Volume 52 | September, 1938 | $1.00 a Year
Number 3 | Pages 259-377 | $1.25 a Number

JOURNAL

OF THE

New England Water Works Association

ISSUED QUARTERLY

Published by
THE NEW ENGLAND WATER WORKS ASSOCIATION
613 Statler Building, Boston, Mass.

Entered as second-class matter September 23, 1903, at the Post Office at Boston, Mass., under Act of Congress of March 3, 1879
Copyright, 1938, by the New England Water Works Association

OFFICERS
OF THE
New England Water Works Association
1938-1939

PRESIDENT

GEORGE A. SAMPSON of Weston & Sampson, Consulting Engineers, Boston, Mass.
(Term expires September, 1939)

VICE-PRESIDENTS

PERCY A. SHAW, Superintendent and Engineer, Water Works, Manchester, N. H.
(Term expires September, 1939)

LELAND G. CARLTON, Water Registrar, Springfield, Mass.
(Term expires September, 1940)

DIRECTORS

FRANCIS H. KINGSBURY, Massachusetts State Department of Health, Boston, Mass.
(Term expires September, 1939)

HAROLD L. BRIGHAM, Superintendent, Marlborough Water and Sewage Commission, Marlborough, Mass.
(Term expires September, 1940)

HORACE L. CLARK, Superintendent, Sanford Water District, Sanford, Me.
(Term expires September, 1941)

PAST PRESIDENTS

(Members of Executive Committee)

HARRY U. FULLER, Engineer, Portland Water District, Portland, Me.

WARREN J. SCOTT, Director, Bureau of Sanitary Engineering, Connecticut State Department of Health, Hartford, Conn.

SECRETARY

FRANK J. GIFFORD, Dedham, Mass.

TREASURER

ABEL REYNOLDS, Treasurer, New England Water, Light & Power Associates, Providence, R. I.

EDITOR

GORDON M. FAIR, 112 Pierce Hall, Harvard University, Cambridge, Mass.

THE ASSOCIATION was organized in Boston, Mass., on June 21, 1882, with the object of providing its members with means of social intercourse and for the exchange of knowledge pertaining to the construction and management of water works. From an original membership of only TWENTY-SEVEN, its growth has prospered until now it includes the names of 800 men. Its membership is divided into six classes, viz.:

A Member shall be an officer or employee of a public or private water works, an engineer, chemist or other person qualified to aid or interested in the advancement of knowledge relative to water works.

An Honorary Member shall be a person of acknowledged eminence in some branch of water supply or of engineering.

A Life Member shall be a member whose service to the Association entitles him to special recognition by the Association.

A Junior shall be not less than eighteen years nor more than twenty-five years of age, a student or connected with water supply work.

An Associate shall be either a person, firm or corporation engaged in manufacturing or furnishing materials or supplies for the construction or maintenance of water works.

A Corporate Member shall be either a Water Board, Commission, Company or Municipal Corporation.

The initiation fees and annual dues are as follows:

	Initiation Fees		*Annual Dues*
Members	$ 3.00	Members	$ 6.00
Juniors	1.00	Juniors	3.00
Associates	10.00	Associates	20.00
Corporate Members	10.00	Corporate Members	16.00

This Association has at least eight regular meetings each year, of which five are held in Boston, one in northern New England, one in southern New England, and one, the annual convention, held in September on such date as the Executive Committee may designate.

The LOCK JOINT "Book of Experience"

Installing Pipe for the City of Little Rock, Arkansas

10,000 Flawless Expansion Joints

ON THE 32 mile pipe line of 39″ diameter Lock Joint Reinforced Concrete Pressure Pipe recently completed for the City of Little Rock, Arkansas, *not one* of the more than 10,000 joints showed any signs of leakage during the tests for final acceptance of the line.

In fact, the results of these tests showed the measured leakage to be less than ten percent of that permitted under the specifications, proving again the superior watertightness of Lock Joint Pipe Lines.

LOCK JOINT PIPE CO., Ampere, New Jersey
PRESSURE : SUBAQUEOUS : SEWER : CULVERT

LOCK JOINT Reinforced CONCRETE PRESSURE PIPE

EVERYBODY'S TALKING ABOUT

The PITTSBURGH IMO WATER METER

The first practical innovation in domestic water meter design and construction to be offered the American Water Works trade in over 50 years.

The Sensation at the A. W. W. A. Convention in New Orleans

Write for Catalog

THE MOST ACCURATE WATER METER EVER COMMERCIALLY BUILT

PITTSBURGH EQUITABLE METER CO., PITTSBURGH, PA.

Scene on 48" all-Dresser-coupled steel transmission line constructed in early part of 1938, under supervision of Newark, (N. J.) Bureau of Water officials, from Belleville Reservoir to the North Newark city line.

In NEWARK as elsewhere!

Now Newark, busy New Jersey metropolis, installs an all-Dresser-coupled water line! Size: 48"; test pressure: 200 lbs. per sq. in. with all couplings bottle-tight; reasons for Dresser-coupling this line: tightness, flexibility, simplicity, speed, and TRUE economy! Line was backfilled promptly as laying progressed.

A METROPOLITAN TREND!

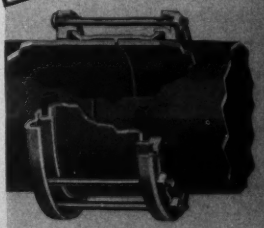
Many large and important cities are Dresser-coupling users. To mention a few:

Buffalo, N.Y.
Cleveland, Ohio
Detroit, Mich.
Philadelphia, Pa.
San Francisco, Cal.
St. Louis, Mo.

FIVE REASONS WHY MODERN WATER LINES ARE DRESSER-COUPLED:

1. PERMANENT TIGHTNESS—proved for 50 years, on 150,000 miles of pipe.
2. FLEXIBILITY—normal pipe movements—present in every line—are absorbed.
3. SIMPLICITY—joints are "factory-made"; ordinary labor can install.
4. STRENGTH—predetermined; joints safely withstand any specified pressure.
5. TRUE ECONOMY—a truly lower joint cost throughout the life of the line.

Write for our General Catalog No. 36.



Cutaway view of Dresser Coupling, Style 38, showing working principle. Note that plain-end pipe is used. The resilient rubber-compound gasket, fusing with the pipe, safely absorb pipe movements, thus preventing failures that often occur with rigid joints.

THE MODERN TREND IS TO DRESSER COUPLINGS

S. R. DRESSER MFG. COMPANY, BRADFORD, PA. • 230 Park Avenue, New York, N.Y. • Peoples Gas Building, Chicago, Ill. • Shell Building, Houston, Tex.
1038 Polk Street, San Francisco, Calif. • *In Canada:* Dresser Mfg. Company, Ltd., 90 Front Street, West, Toronto, Ontario

Table of Contents

PAGE

Development of the Water Supply of the City of New York. By Joseph Goodman 259

Calculation of Chemical Dosages Required for the Prevention of Corrosion. By Edward W. Moore 311

Maintaining a Distribution System in Northern New England. By James A. Sweeney 318

Bristol's New Filtration Plant. By James A. Newlands 324

Thread Gage Design and Threading Problems. By Oscar E. Koehler 331

Experiences in Watershed Sanitation. By Marshall S. Wellington .. 343

Connecticut's New Plumbing Regulations as Affecting Water Supplies. By Leslie K. Sherman 351

Economic Design of Hydraulic-fill Dam Sections. By Harry H. Hatch 364

New England Water Works Association
ORGANIZED 1882

Vol. LII September, 1938 No. 3

This Association, as a body, is not responsible for the statements or opinions of any of its members

DEVELOPMENT OF THE WATER SUPPLY OF THE CITY OF NEW YORK

BY JOSEPH GOODMAN*

HISTORICAL

The present City of New York is the result of the consolidation in 1898 of various communities located in the vicinity of New York harbor, which are now included in the boroughs of Manhattan, the Bronx, Brooklyn, Queens and Richmond. Their water supplies were developed without regard to the present city limits, and it was not until 1917 that New York was served by a system planned for the city as a whole.

The Borough of Manhattan, constituting the old City of New York, had until 1842, no general water supply system, although its population at that time amounted to over 300,000. The early settlers of Manhattan Island obtained water for domestic purposes from shallow wells which were at first constructed by individual enterprise. The first public well was dug in front of the old fort at Bowling Green in or about the year 1677. Additional public wells were sunk in the streets from time to time, as required, the city bearing part of the expense and part having been assessed on the property benefited. In 1776, when the population reached 22,000, a reservoir was constructed on the east side of Broadway between Pearl and White streets. Water was pumped from wells sunk near the famous "Collect" Pond east of the reservoir, and from the pond itself, and was distributed through hollow logs laid in the principal streets. In 1800, the Manhattan Company (now the Manhattan Bank) sunk a well at Reade and Centre streets, pumped water therefrom into a reservoir on Chambers Street and distributed it hence through wooden mains to a portion of the community which, at that time, consisted of about 60,000 inhabitants. The maximum amount supplied by this company was 700,000 g.p.d. In 1830, a tank for fire protection was constructed

*Chief Engineer of Water Supply, Department of Water Supply, Gas & Electricity, New York City.
[*Read September 22, 1938.*]

by the City at 13th Street and Broadway; this tank was filled by pumping from a well sunk for the purpose, and the contents distributed through two lines of 12-in. cast-iron pipe, one extending down The Bowery to Chatham Square and the other through Broadway and Canal Street. This was the beginning of the public water-works of New York City. The well was 16 ft. in diameter and 112 ft. in depth, 98 ft. of which were excavated through solid rock. At the bottom of the well, two galleries extended, 6 ft. by 4 ft. in cross-sections; one 25 ft., and the other 75 ft. in length. The daily yield of the well amounted to 21,000 gal. and was pumped by a 12-h.p. Stearn engine into a cast-iron tank of 43-ft. diameter and 20½-ft. height, enclosed in an octagonal stone building.

As the population of the City increased, the well waters became brackish or polluted with organic matter and insufficient in quantity. To meet ordinary domestic needs, main dependence was placed upon cisterns supplied from rain caught upon the roofs; water secured from a few springs in the upper part of the City was sold from large casks at two cents a pail.

After entertaining numerous schemes for a suitable source of supply, among which were Rye Pond, Bronx and Byram Rivers in Westchester County, Passaic River in New Jersey and artesian wells on Manhattan Island, it was decided to build an aqueduct from the Croton River to the City, to be supplied by one storage reservoir; this aqueduct (known today as the Old Croton Aqueduct), with a capacity of 90 m.g.d., was placed in service in 1842, its completion having been expedited by the great conflagration of 1835. This was an event of great importance in the history of older New York. The distribution reservoirs were at 42nd Street (abandoned in 1890), and in Central Park, south of 86th Street (abandoned in 1925). In the drought of 1869-1870, the right was secured to draw down six of the lakes and ponds in the Croton watershed. Boyd's Corners Reservoir was then constructed in 1873 and Middle Branch in 1878. In due course the old Croton aqueduct became inadequate, and in 1883 a commission was formed to build a second one from the Croton watershed, as well as additional storage reservoirs in that watershed. The second aqueduct, known as the New Croton Aqueduct, was under construction from 1885 to 1893 (though it was used as early as 1890), and has a capacity of 285 m.g.d.

West Bronx was annexed to the old City of New York in 1874 and East Bronx in 1895. The system of the New York and Westchester Water Company which supplied the villages of Williamsbridge and Wakefield and the towns of Westchester and Pelham from

the Hutchinson River was acquired by the City in 1903; the Upper New York City Water Company which supplied the village of Eastchester was acquired by the City in 1905. A municipal supply from the Bronx and Byram rivers was made available in 1895. The waters from this watershed, yielding about 20 m.g.d., were originally delivered into a 48-in. cast-iron pipe line over fifteen miles long, leading from the former Kensico Lake to the Williamsbridge Reservoir, (abandoned in 1934), in the Bronx. This lake was merged in the new Kensico reservoir, and at that point the waters from the Bronx and Byram watersheds become merged with the new Catskill supply.

The former City of Brooklyn, like the former City of New York, did not develop a public water supply system until its population had reached nearly 300,000, the use of local wells and cisterns being the only sources of supply prior to 1859. In that year, the city began delivering water collected on the south side of Long Island into its distribution system, pumping this water at the Ridgewood North Side Pumping Station. The original works ran easterly to the Hempstead Valley. Later they were extended to Massapequa, Long Island, and the large Milburn and the Ridgewood South Side pumping stations constructed.

For the Borough of Queens, no municipal waterworks of magnitude have been constructed. Prior to 1913 the First Ward was served by three local municipal pumping stations and by private water companies. Between 1913 and 1917 it was served largely from the Brooklyn watershed. The Third Ward, prior to 1917, was served by two municipal pumping stations, while the Second, Fourth and Fifth Wards were supplied by private water companies, their sources of supply being ground water collected by means of driven wells.

On April 20, 1922, that part of the plant of the Citizens Water Supply Company supplying the Second Ward was acquired through condemnation by the City, and at present is municipally operated, and on April 15, 1931, the Fifth Ward plant of the Long Island Water Corporation was acquired by purchase. The Citizens Water Supply Company was incorporated on June 1, 1893, and began to supply water in the following year; the Long Island Water Corporation was incorporated on March 27, 1884, and its first water works system at Far Rockaway was constructed in 1885.

Prior to 1917, the Borough of Richmond was dependent for its supply on ground water drawn from wells. Until 1909, except as to Tottenville, it was served by private water companies. The principal of these companies, the Staten Island Water Supply Company, incorporated on September 19, 1878, and the Crystal Water Supply

Company, incorporated on March 16, 1883, were in 1909 acquired by the City. The last of the private companies in this borough (the South Shore Water Works Company, which was originally incorporated on July 10, 1889), was acquired by the City in 1917.

Some 36 years ago, the necessity was foreseen of providing a large additional water supply for the use of Greater New York, and in 1902 definite steps were taken to formulate and execute such a plan. In that year a commission of engineers was appointed which, after careful study, recommended that the city go to the Catskills for additional water. In 1905 the Board of Water Supply—not to be confused with the Department of Water Supply, Gas and Electricity—was created by act of the Legislature, and proceeded forthwith to plan and construct the works for impounding the waters of the Esopus, one of the four watersheds in the Catskills, upon which the city had planned to draw, and for delivering such waters throughout New York City. This monumental work, commonly known as the Catskill System, was successfully completed and turned over to the Department of Water Supply, Gas and Electricity for operation in 1917. The second stage of the Catskill development, which involved the construction of the Schoharie reservoir and Shandaken tunnel, was finished and turned over to the Department on June 1, 1928. The Schoharie supply was used on and after February 3, 1924, when the tunnel was opened. Under a resolution of the Board of Estimate and Apportionment, adopted on June 17, 1921, the Board of Water Supply was empowered to investigate sources of additional supply for the City and the more adequate extension of existing and future water supplies.

In 1927, the Board of Water Supply submitted to the Board of Estimate and Apportionment a plan recommending the upper portion of the Rondout watershed and the tributaries of the Delaware River lying wholly in the State of New York as the most available and economical sources of new water supply for New York City. The project was approved by the Board of Estimate and Apportionment in 1928, and by the Water Power and Control Commission in 1929, but was held back because of action brought by the State of New Jersey in the U. S. Supreme Court, to enjoin the City and State of New York from using the waters of any of the tributaries of the Delaware River. In May, 1931, the U. S. Supreme Court upheld the right of New York City to augment its water supply from the headwaters of the Delaware River. The City, however, was permitted to divert at the present time only 440 m.g.d. from the tributaries of the Delaware River instead of the 600 m.g.d. planned. It is

estimated that the upper portion of the Rondout watershed will yield 100 m.g.d. The combined watersheds will therefore yield 540 m.g.d. The upper Rondout and Delaware watershed development, including the proposed aqueduct to the City, is generally referred to as the Delaware System.

It is proposed to develop the upper Rondout and tributaries of the Delaware River in two or three stages, and as it will require about eight years to develop the first stage and deliver an additional supply of water to the City, the Department, in order to insure a sufficient supply of water up to the time when the Delaware supply will become available, has planned the construction of a pumping plant at Rondout Creek for pumping water from the Creek into the Catskill aqueduct, and the construction of additional artesian wells in Long Island and in Richmond.

Gratifying results have also been obtained in reducing consumption by elimination of waste through holding pressures within reasonable limits, by carrying on a systematic survey to locate and stop leaks in the distribution mains and appurtenances and house services outside of buildings, and by systematic house-to-house inspection to locate leaky fixtures within buildings and compelling repairs to be made.

Watersheds, Reservoirs and Aqueducts

The municipality now has available as sources of supply (1) Schoharie and Esopus creeks in the Catskills where water is collected in the Schoharie and Ashokan reservoirs, (2) Bronx and Byram rivers in Westchester County, where the water is stored in Byram and Wampus ponds and in the enlarged Kensico Reservoir, now part of the Catskill System, (3) Croton River in Putnam and Westchester counties, where the water is collected in 12 reservoirs and 6 controlled lakes, (4) Brooklyn and Ridgewood watersheds on the south side of Long Island, where water is obtained from small streams, infiltration galleries and driven wells, (5) Borough of Queens, where water is obtained from driven wells, (6) Borough of Richmond, where water is obtained from driven wells.

Brief descriptions of the various systems follow. See Figure 1.

Croton System

The Croton River is formed by three branches, known respectively as the East, Middle and West Branch, which rise in the southern part of Dutchess County, flow in a southerly direction on through Putnam County and unite near its southerly boundary. The river

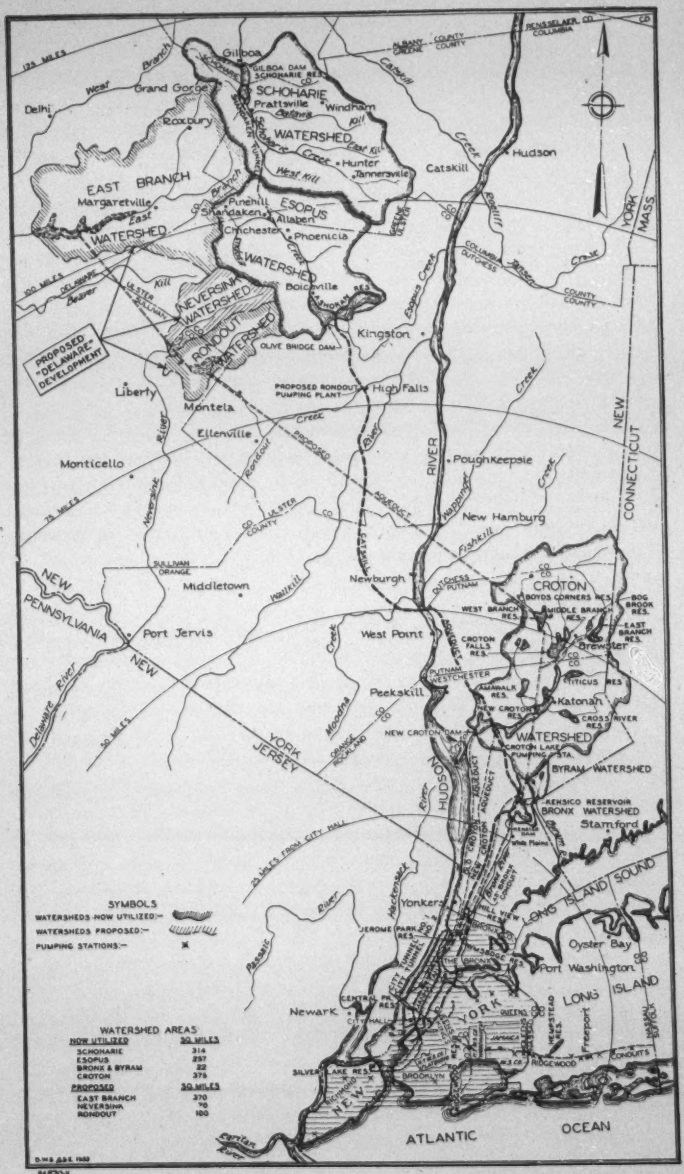


FIG. 1—SOURCES OF WATER SUPPLY OF THE CITY OF NEW YORK SHOWING WATERSHEDS AND AQUEDUCTS.

continues in a southwesterly direction across Westchester County to the Hudson River, into which it empties at Croton Point, 22 miles from the northerly limits of New York City. The principal tributaries of the Croton are the Titicus, Cross, Kisco and Muscoot rivers.

The watershed extends about 33 miles north and south and eleven miles east and west; it lies almost entirely within the State of New York, only a small portion being in Connecticut. Its area is 375 sq. miles above the New Croton Dam, and it may be relied upon to yield at least 300 m.g.d., the yield in the past 68 years having averaged 400 m.g.d. Its waters are collected through 12 storage reservoirs and 6 controlled lakes having an aggregate storage capacity of 103,100 m.g. The lowest and largest of the reservoirs is Croton Lake which is formed by the New Croton Dam; it is about 20 miles in length and has an available storage capacity of 33,885 m.g. The population on the watershed is about 50,000, mainly concentrated in several small towns and villages. The watershed is very hilly. The surface soil is composed principally of sand and gravel; clay, hardpan and peat are found in a few localities, but, only to a very limited extent. The rock formation consists generally of gneiss. Strata of limestone, some micaceous and talcose slates, veins and granite serpentine and iron ore occur in a few places. The Croton water is a soft water, although not so soft as the Catskill water. To protect the supply a margin of about 300 ft. has been acquired by the City around all reservoirs and along some of the tributary streams.

The new Croton dam, an imposing structure (Figs. 2 and 3), was constructed between 1892 and 1905 at a cost of approximately $17,000,000 including land, the cost of the dam itself having been close to $7,000,000. It is built across the valley of the Croton River, three miles above the point where it empties into the Hudson River. Including a curved spillway 1,000 ft. long, it has a total length of 2,168 ft. It is founded upon bed rocks of gneiss and limestone. The maximum width at the base is 206 ft., the maximum height 296.8 ft., and minimum thickness at top 18 ft. With the exception of 128 ft. of earth section with masonry core, the entire dam is partly of cyclopean, but mainly rubble masonry, faced above the backfilling with ashlar masonry. The spillway of the dam is at El. 199.06 ft.; two-foot permanent flashboards are set on top of the spillway.

Old Croton Aqueduct. The Old Croton aqueduct (Fig. 4) was constructed in 1837 to 1842. It begins at Croton Lake, follows the Croton River to a point near its mouth, and then the Hudson River to Yonkers. Here it crosses the Sawmill River and Tibbets Brook, and continues to the Harlem River, which it crosses on High-

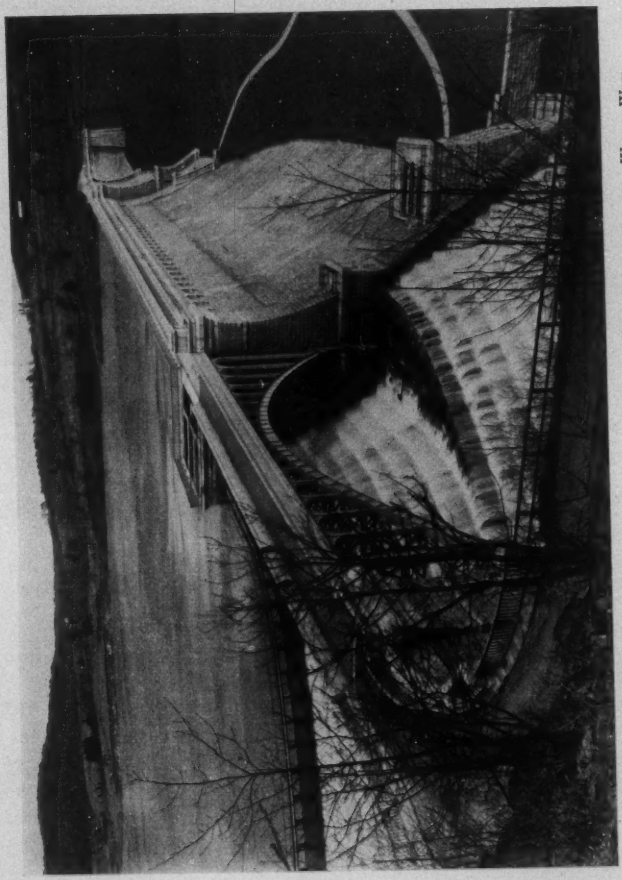


FIG. 2.—CROTON DAM AND SPILLWAY, WITH FLOOD WATERS DISCHARGING OVER THE WASTE WEIR.

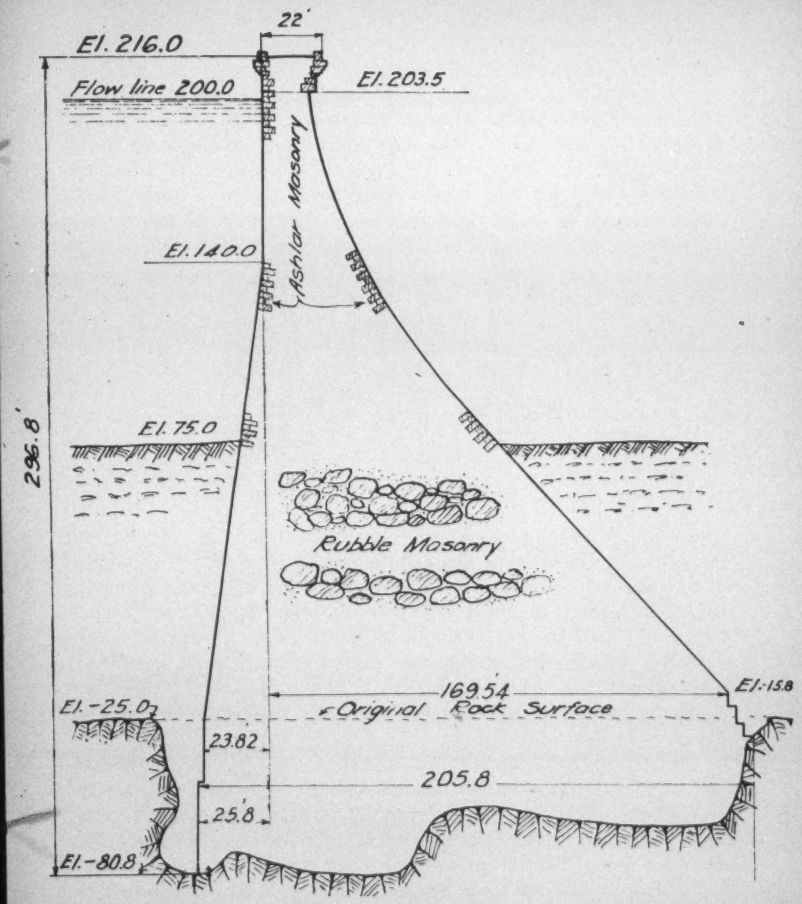


FIGURE 3

NEW CROTON DAM. MAXIMUM SECTION. Elevations refer to Croton Datum, which is 0.94 ft. below Mean Sea Level at Sandy Hook.

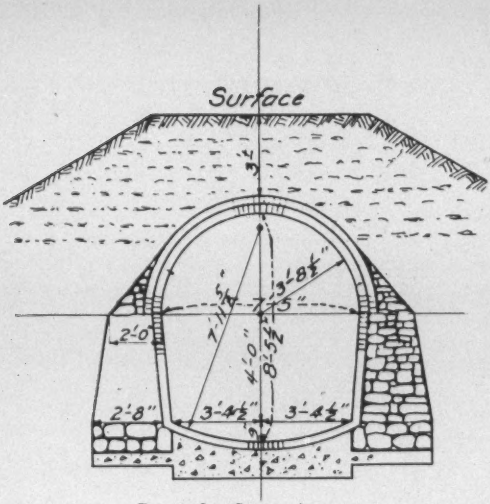


FIG. 4—OLD CROTON AQUEDUCT.

bridge, thence to the receiving reservoir in Central Park. The standard section is of horse-shoe shape containing 53.34 sq. ft. It is founded on concrete 3 to 12 in. thick; the side walls are of rubble masonry. Sides and bottom are lined with 4 in. of brick, and the top arches are of 8-in. brickwork. Valleys, as a rule, are crossed on earth embankments with dry rubble walls. The grade in general is 0.021%. Highbridge is crossed by means of a 90-in. steel pipe, Manhattan Valley by means of two lines of 36-in., one line of 48-in. and one line of 60-in. cast-iron pipe.

While repairs to this aqueduct have been made from time to time, and some short sections built on embankments have been reconstructed, the aqueduct is still in generally good condition, but is capable of delivering without excessive leakage only about 45 m.g.d., or about one half of the full capacity for which it was originally designed.

Practically all the Croton water reaching Manhattan is carried to the gatehouse at 135th Street and Convent Avenue, except that taken from the new Croton Aqueduct at the 179th Street Pumping Station. From the 135th Street Gatehouse, all Croton water goes by gravity into the mains either directly or through the distributing reservoir in Central Park, except that which is sent to the 98th Street Pumping Station.

New Croton Aqueduct. The New Croton Aqueduct was constructed in 1885 to 1891. It consists essentially of three parts:

1. A masonry conduit from the inlet gatehouse which is located near the Old Croton Dam, and three miles north of the New Croton Dam, to Mosholu Avenue near the Jerome Park Distributing Reservoir, a distance of 23.92 miles. The invert at the gatehouse is 60 ft. below the elevation of the spillway at the new Croton dam, the grade thence being uniformly 0.7 ft. per mile, except for the inverted siphon under Gould's Swamp near Tarrytown. The nominal capacity of this stretch is 285 m.g.d. This portion of the aqueduct is of horseshoe section (Fig. 5), except the Gould's Swamp Siphon, which is

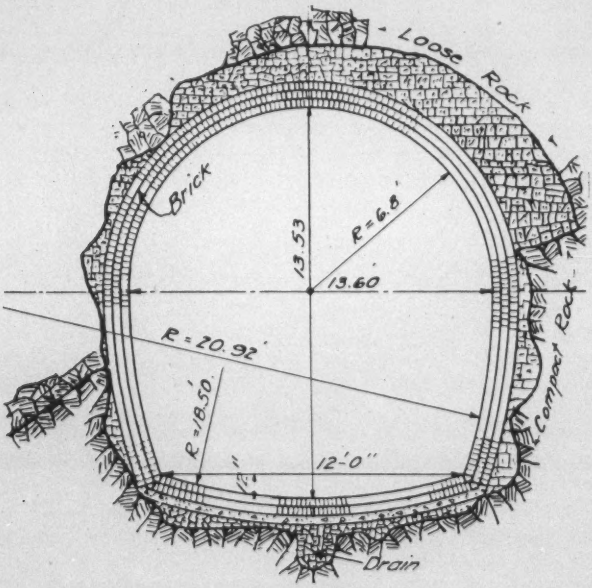


FIG. 5—NEW CROTON AQUEDUCT. GRADE TUNNEL IN COMPACT AND IN LOOSE ROCK.

circular, 14 ft. 3 in. in internal diameter, and 1,135 ft. long. It was constructed mainly in tunnel and follows a southerly direction along Pocantico River, Sawmill River and Tibbets Brook. The aqueduct is lined with brickwork, varying from 12 to 24 in. for the sides

and arch, and from 8 to 24 in. for the invert, according to external pressure; the invert was laid on a foundation of concrete and rubble. The space between the sides and roof of the tunnel excavation and the brick lining was filled with rubble masonry to a level of 4 ft. above the crown of the intrados of the arch.

2. A masonry conduit under pressure from Mosholu Avenue to gatehouse on Manhattan Island at 135th Street and Convent Avenue (Fig. 6). This portion forms a long inverted siphon; its cross-

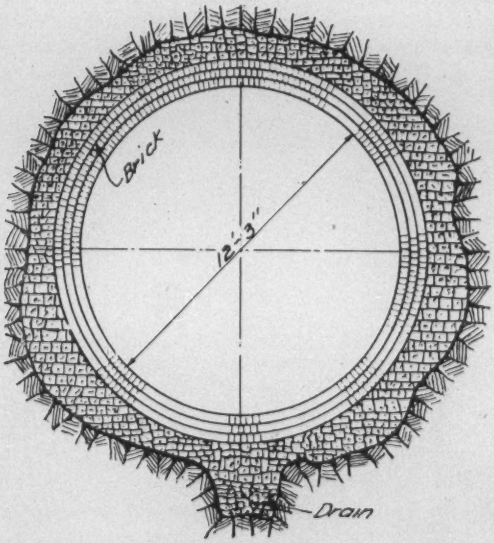


FIG. 6—NEW CROTON AQUEDUCT. PRESSURE TUNNEL.

section is circular, the inner diameter being 12 ft. 3 in., except in the tunnel under the Harlem River, where it was reduced to 10½ ft. to increase the velocity of current in order to prevent deposit of silt. To avoid heavy land damages, the aqueduct at Mosholu Avenue was depressed 115.64 ft. by an incline having a 10% grade, and continued on a grade of 0.7 ft. per mile, to a point within 1,100 ft. of the Harlem River. Here the aqueduct was lowered 127.5 ft. on a 15% grade, and then 172 ft., passing under the Harlem River 300 ft. below high water, descending on a 1% grade. On the Manhattan side, the conduit ascends from the shaft to the gatehouse at a grade of 0.065%. The

nominal carrying capacity of this stretch of the aqueduct is 250 m.g.d., the difference being allowed for the water taken out of Jerome Park Reservoir for the Bronx supply; this capacity is further reduced by the additional head maintained at the 135th Street Gatehouse.

3. Pipe lines from the 135th Street Gatehouse to the gate at the new Central Park Distributing Reservoir. Seven lines of 48-in. cast-iron mains are laid from the gatehouse to 125th Street; three are continued to the reservoir, and the other four connected with the distribution system at various points.

Croton Lake Pumping Plant. The pumping plant installed at the Croton Lake gatehouse is comprised of three motor-driven centrifugal units each of 60-m.g.d. capacity.

The plant, which has been in operation since March 15, 1932, is designed to lift water from the Croton Lake Reservoir, discharging it through a 72-in. steel line approximately 1,600 ft. long, into the Catskill aqueduct, at a level of about 170 ft. above that of the surface of Croton Lake. The station is not operated continuously, but only over such periods as may be necessary to equalize the difference in the quantity of stored water in the Catskill and Croton watersheds, thus providing greater flexibility in the operation of the city's water supply.

Bronx and Byram Systems

Work on the development of the Bronx River and Byram River watersheds, covering 13.33 and 8.66 sq. miles respectively, was commenced in 1880, but owing to long negotiations with riparian owners on the Byram River in Connecticut, the entire construction was not completed until 1897, although part of the supply was made available in 1884.

A small dam, forming what is known as Byram Pond, was constructed on the Byram River (the outlet of Byram Lake), just below the point where the Wampus River (the outlet of Wampus Pond), unites with it, and about 1,100 ft. north of the Connecticut State Line. From this dam, the waters of the Byram River are led into the Bronx watershed through a tunnel, and then an open channel, 3,800 ft. in length. The dam, which was constructed across the Bronx River near the Kensico Station of the Harlem Railroad, has been replaced by the new Kensico Dam, and the runoff of the Bronx and Byram watersheds is merged with the Catskill water stored in Kensico Reservoir. A line of 48-in. cast-iron pipe, 15.2 miles in length, was laid from Kensico Dam to the Williamsbridge Distributing Reservoir; the inflow into this pipe line is now controlled at the new Kensico Dam.

Catskill System

Catskill water has its origin in the Esopus and Schoharie watersheds. These watersheds, occupying the central and eastern portions of the Catskill mountains, collect the stream flow from the mountains of sparsely populated areas which they embrace. The Esopus watershed, draining naturally into the Hudson River, has an area of 257 sq. miles. The Schoharie watershed, draining to the north into the Mohawk River, has an area of 314 sq. miles. The combined drainage area of these two sources is therefore 571 sq. miles, and it is conservatively estimated that even during a series of extraordinarily dry years, at least 500 m.g. of water daily can be drawn. The rock formations included within the Esopus and Schoharie watersheds are of sandstone and shale, and the water, in consequence, is of an unusual degree of softness. The greater part of the water from these two drainage areas is stored in the Ashokan Reservoir, the balance being held in the Schoharie Reservoir.

Schoharie Creek lies north of the Esopus, in the heart and higher section of the Catskill mountains. Gilboa Dam, built across the creek at Gilboa in Greene County, is located about four miles northeast from the Grand Gorge Station of the Ulster and Delaware Railroad. Grand Gorge Station is 66 miles by rail from Kingston, and 155 miles from New York. It is 120 miles, in an air line, north of the City Hall, and 35 miles west of the Hudson River. The tributaries have their source at elevations of nearly 2,000 ft. in the localities of Hunter, Windham, Prattsville and Grand Gorge in Greene, Delaware and Schoharie counties. The watershed is similar in character to the Esopus, chiefly steep mountains of shale and sandstone, which are covered with wild forest growth. These streams are flashy. There are large freshets in the spring with very little flow during the summer months. Because of this steep and rocky character, the flow in the streams is a large proportion of the rainfall.

While the Esopus flows out of the Catskills through the southerly gateway toward Kingston and the Hudson River, the Schoharie flows out through the northerly portals to the Mohawk River near Amsterdam. It lies at a sufficiently high elevation to enable the flow to be intercepted by a dam at Gilboa, reversing the direction and sending the water through an 18-mile tunnel under the intervening Shandaken mountain range into Esopus Creek at Allaben in Ulster County. The water thus diverted joins the water of the Esopus and finds its way for 15 miles into the Ashokan Reservoir, where it is available for the main Catskill aqueduct.

Shandaken Tunnel. The contract for the construction of the

Shandaken Tunnel was awarded on November 9, 1917, for $12,138,738.

The intake is located about 3½ miles north of the village of Prattsville. From here, the tunnel extends in a generally southeasterly direction until just south of the village of Allaben, where it discharges into the Esopus Creek. The tunnel is horse-shoe shaped in section, concrete lined, with inside dimensions of 11 ft. 6 in. in height by 10 ft. 3 in. in width, and provides for a uniform slope of 4.4 ft. per mile, except for the northerly 3½ miles, which are depressed, making this portion a pressure tunnel. Seven intermediate construction shafts were sunk, the aggregate depth of shaft being 3,238 linear feet, the maximum depth of a single shaft being 630 ft. The minimum distance between shafts is 1.3 miles, the maximum 2.7 miles. All shafts are circular and concrete lined. The upper portion of the intake shaft is so constructed that it acts as a Venturi meter, and the building over this shaft contains the control gates and the keeper's residence.

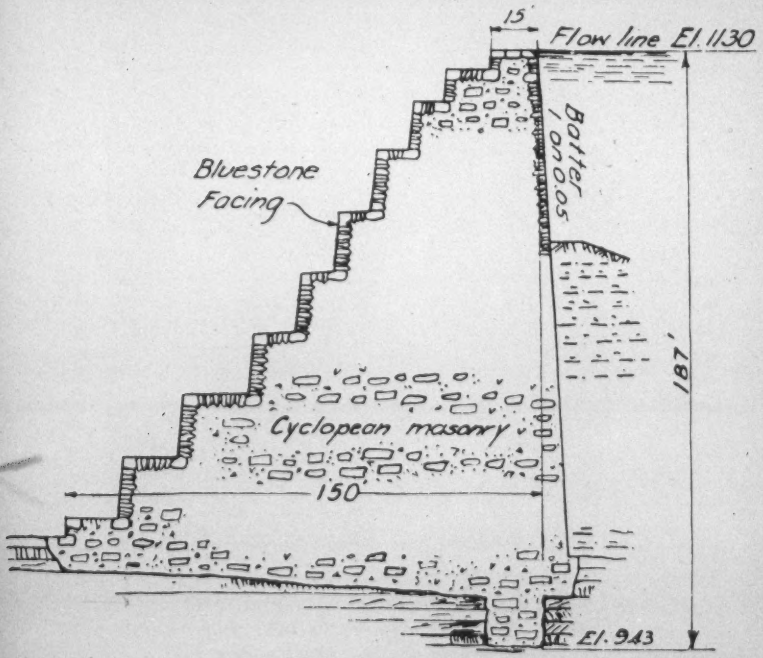


FIG. 7—GILBOA DAM. MAXIMUM SECTION.

FIG. 8.—SCHOHARIE RESERVOIR, SHOWING FLOOD FLOW DISCHARGING OVER SPILLWAY OF GILBOA DAM.

Gilboa Dam. The Gilboa Dam (Fig. 7) is composed of two parts—an overfall masonry portion about 1,300 ft. in length and having a maximum height of about 160 ft., with the crest at El. 1130 ft. above sea-level, and an earth section at El. 1150, with core-wall, approximately 1,000 ft. long. Along the downstream toe of the dam there is a channel for collecting and conveying the overflow flood waters into the present channel of Schoharie Creek below the dam.

Schoharie Reservoir. The Schoharie Reservoir (Fig. 8) serves both as a diverting and as a storage reservoir. It stores 19,583 m.g., so that a large part of the storage for the Schoharie has been provided in the Ashokan Reservoir. It holds only 0.14 of the amount of the total flow of the Schoharie for an average year, while the Ashokan holds 1.03 times the flow of Esopus Creek. The tunnel was therefore built large enough so that in times of plenty the water can be delivered through to Ashokan at a rate of 650 m.g.d., more than twice the normal rate of contemplated draft from Schoharie.

The reservoir is approximately five miles long and about one mile in maximum width, reaching from Gilboa to Prattsville, the former being the only village disturbed. No railroad was affected, but the construction of 12.4 miles of highways was required to replace 13.6 miles that were abandoned. As at Ashokan, the City has acquired a marginal strip around the shore line for sanitary protection of the water.

Ashokan Reservoir. The Ashokan Reservoir is located in Ulster County, about 14 miles west from the City of Kingston. Its cost, together with that of the necessary appurtenant works, including the relocation of highways and of the Ulster and Delaware Railroad, was nearly $20,000,000. This reservoir has a water surface of 8,180 acres, and an available capacity of 127,691 m.g.; this capacity can be increased to 130,428 m.g. by placing flashboards on the spillway. The principal structures which form this reservoir are the Olive Bridge dam (Fig. 9), built of masonry, across the Esopus Creek, the earthen dikes or dams which close in the gaps between the hills forming the natural walls of the reservoir, the dividing dike and weir, which separates the reservoir into two basins, and the waste weir, over which the surplus flood waters may be safely discharged. The Ashokan Reservoir is divided into two parts, which are known as the East basin and the West basin (Fig. 10), the full water surface elevation of the West basin being at 590 ft. above mean tide at New York, while the East basin is at an elevation 3 ft. lower. This division into two basins was made so as to provide greater flexibility of operation

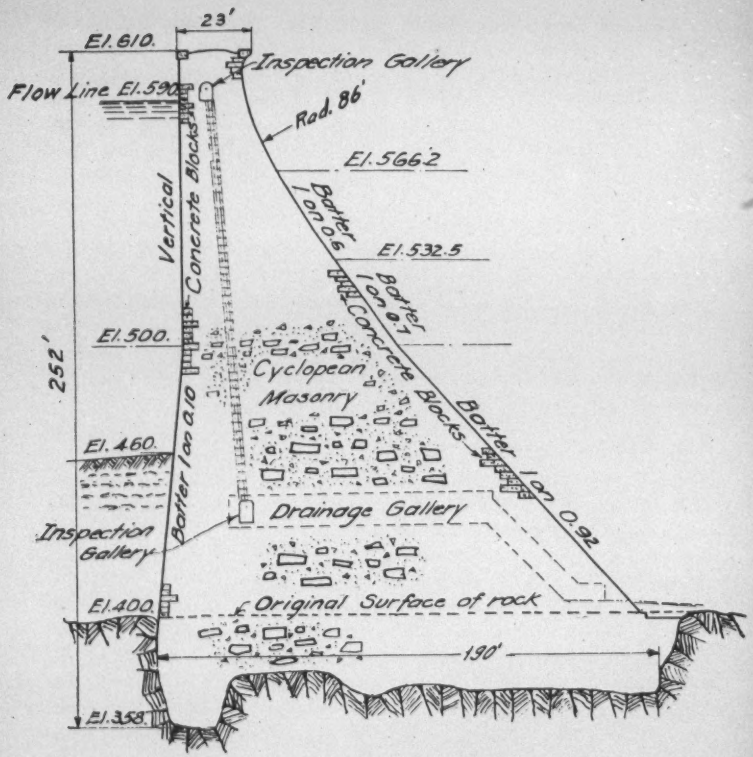


FIG. 9—OLIVE BRIDGE DAM. MAXIMUM SECTION.

and thus at all times insure the drawing of water from that part of the reservoir in which the conditions are the most favorable.

The masonry portion of the Olive Bridge dam is founded on solid ledge-rock and was built of cyclopean concrete faced with smoothly finished concrete blocks. At each end, the masonry section is flanked by earthen dikes. The bottom and slopes of the reservoir basins were cleared of trees, brush and all other objectionable matter; 40 miles of new highway were constructed around the reservoir. This work required the construction of ten new bridges, one of which has a span 200 ft. long, and another a total length of 1120 ft. The

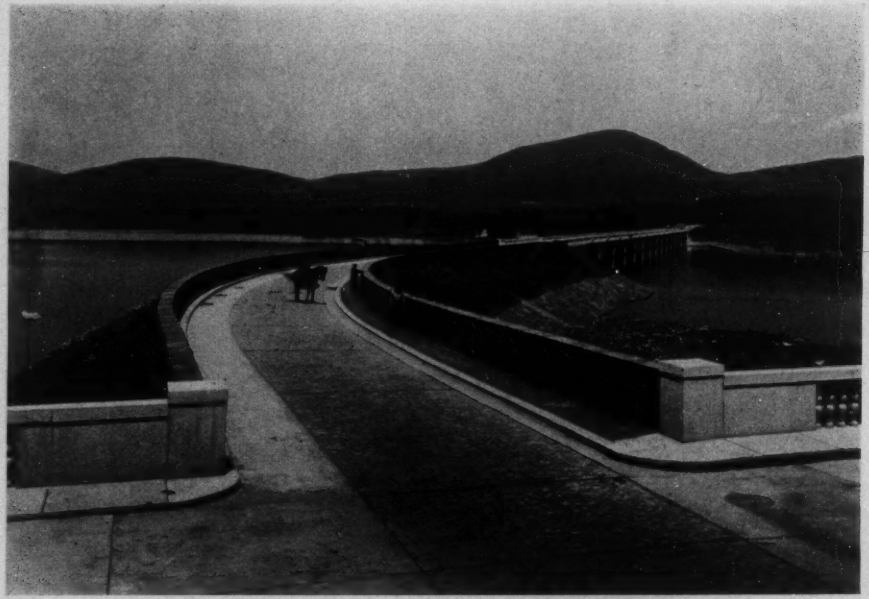


FIG. 10—THE ASHOKAN RESERVOIR SHOWING THE DIVIDING WEIR DIKE, THE ASHOKAN BRIDGE AND PORTIONS OF THE EAST AND WEST BASINS OF THE RESERVOIR.

FIG. 11—THE ASHOKAN AERATOR. THE BUILDING IS THE ASHOKAN SCREEN CHAMBER WHERE THE CATSKILL AQUEDUCT BEGINS.

relocation of the Ulster and Delaware Railroad required the construction of 11 miles of new road-bed and track.

Just below the reservoir, provision has been made for jetting the water into the air in fine spray, thus permitting thorough admixture of oxygen and removal of objectionable gases and the breaking down of other matter causing tastes and odors. The aerator (Fig. 11) consists of a basin approximately 250 ft. by 500 ft., containing about 1600 nozzles, through which jets of water are thrown vertically into the air.

Kensico Reservoir. The Kensico Reservoir, in Westchester County, 30 miles north from the City Hall, was designed to contain sufficient Catskill water for maintaining the supply over a period of about two months, so that the flow to the City will not be interrupted while the 75 miles of aqueduct between it and the Ashokan Reservoir are at any time out of service. This reservoir is formed by the Kensico Dam, across the valley of the Bronx River, about three miles north of White Plains, and 15 miles north of the Hillview Reservoir. Its available capacity with water at spillway elevation is 29,171 m.g. By means of permanent flashboards on the spillway the capacity has been increased to 30,573 m.g. The surface elevation at spillway is 355 ft. above mean tide at New York. The area of its water surface at this elevation is 2218 acres, and the marginal protective strip around its entire circumference is in few places less than 500 ft. wide. The Kensico Dam (Figs. 12 and 13) contains altogether nearly one million cubic yards of masonry—about one-third the volume of masonry placed by the Egyptians in the great pyramid. At the point of greatest height, it rises 307 ft. above the rock foundation on which it rests. A new highway system, rendered necessary by the construction of the Kensico Reservoir, embraced the construction of 15 miles of road on which were a number of bridges, one of them a reinforced concrete structure of five arches, each about 127 ft. long. This bridge carries the highway over an arm of the reservoir and the roadway at the center is 107 ft. above the reservoir bottom.

Catskill water enters the Kensico Reservoir near its upper end and is drawn from the lower end through a system of gates located in chambers about one mile north from the Kensico Dam. At this point, provision is made for controlling the rate at which the water is drawn, for screening and for sterilizing it with liquid chlorine. Here also has been provided a large aeration basin in which the water is thrown into the air through 1,599 nozzles. This operation results in thoroughly mixing the water with air and thus aiding its purification.

The Kensico Dam is located practically on the site of a small

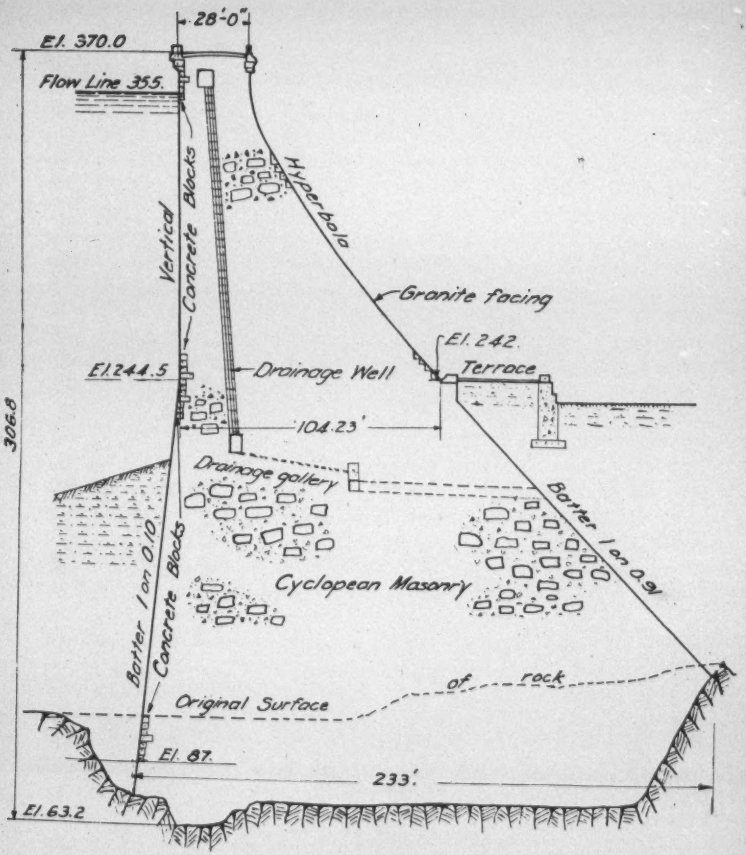


FIG. 12—KENSICO DAM. MAXIMUM SECTION.

original dam which formed the old Kensico Reservoir in which were stored the waters of the Bronx and Byram Rivers. This old reservoir was very much smaller and lower than the present one, and it has been entirely obliterated. The Kensico Dam is a gravity masonry structure built of cyclopean masonry faced on its upstream side with concrete blocks and with granite masonry on its downstream

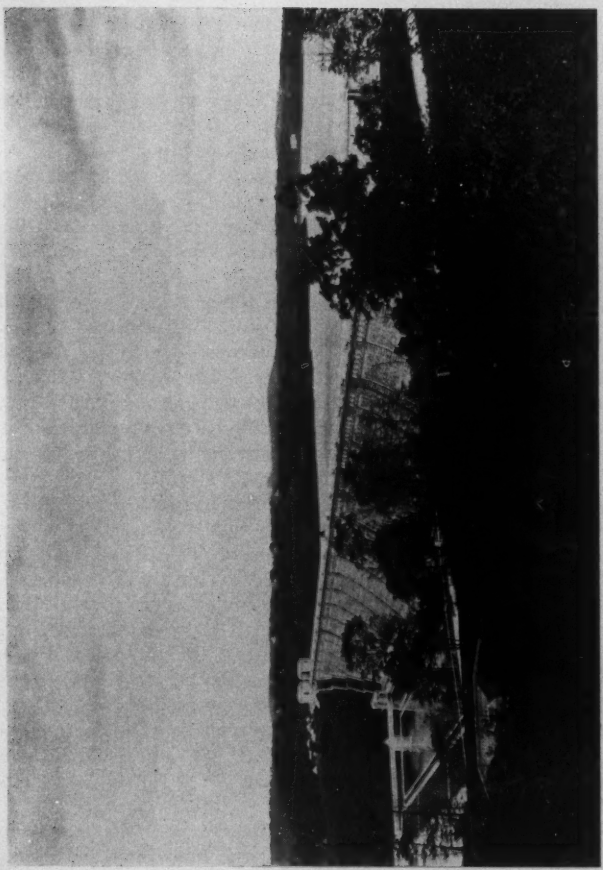


FIG. 13.—THE KENSICO DAM AND PORTION OF THE RESERVOIR WITH THE KENSICO LOWER EFFLUENT CHAMBER IN RIGHT BACKGROUND.

face. In order to provide for the movements which result from seasonal changes of temperature, the dam is divided into sections by expansion joints spaced about 80 ft. apart. Local stone was used for the facing of the dam, and an effort was made to secure as rough and rugged an appearance as was consistent with the principles of the adopted design.

Preliminary surveys for the Kensico Reservoir were begun in May, 1906, and the contract for the construction of the dam was awarded in December, 1909, the amount of the contract being $8,006,300. It was required that the work should be entirely completed by February, 1920. Due, however, to the exceptional manner in which the work was prosecuted, the dam was completed to its full height nearly four years sooner than was thought possible when the contract was prepared.

Hillview Reservoir. The Hillview Reservoir is located in the City of Yonkers, just north of the New York City line, and 15 miles south of Kensico Reservoir. It is an uncovered, artificial reservoir of the earth-embankment type, and is lined with concrete. It has a depth of 36½ ft. and a water surface area of 90 acres. It holds 929 m.g., its function being to equalize the difference between the steady flow in the aqueduct and the use of water in the City, as it varies from hour to hour throughout the day. Its outlet is the vertical downtake shaft of the large City Tunnel No. 1 which extends through the Bronx and Manhattan to Brooklyn with a connection to City Tunnel No. 2 extending through the Bronx, Queens and Brooklyn. The high pressure of the water delivered to the City through these tunnels is due to the elevation of the water surface in Hillview Reservoir, which is 295 ft. above sea level. Catskill water is delivered to the City, 161 ft. higher than Croton water. The reservoir is divided into two basins by a wall 2,740 ft. long that contains the bypass aqueduct, so that either one or two basins may be used, or bypassed, whenever required, directly into the City tunnels. The contract for its construction, including some tunnel work, was awarded in December, 1909. It was first filled on December 29, 1915, the cost of the completed work being $3,212,900.

Silver Lake Reservoir. This distribution reservoir for Staten Island is about 2,400 ft. long by 1,500 ft. wide, uncovered and formed by the natural ground and by artificial embankments with core-walls. It is not lined with concrete. A dividing dike paved with concrete divides the reservoir into two basins, holding, together, 435 m.g. From a gate chamber built in this dike, reinforced concrete conduits extend to the boundary of the reservoir. Cast iron and steel pipes connect

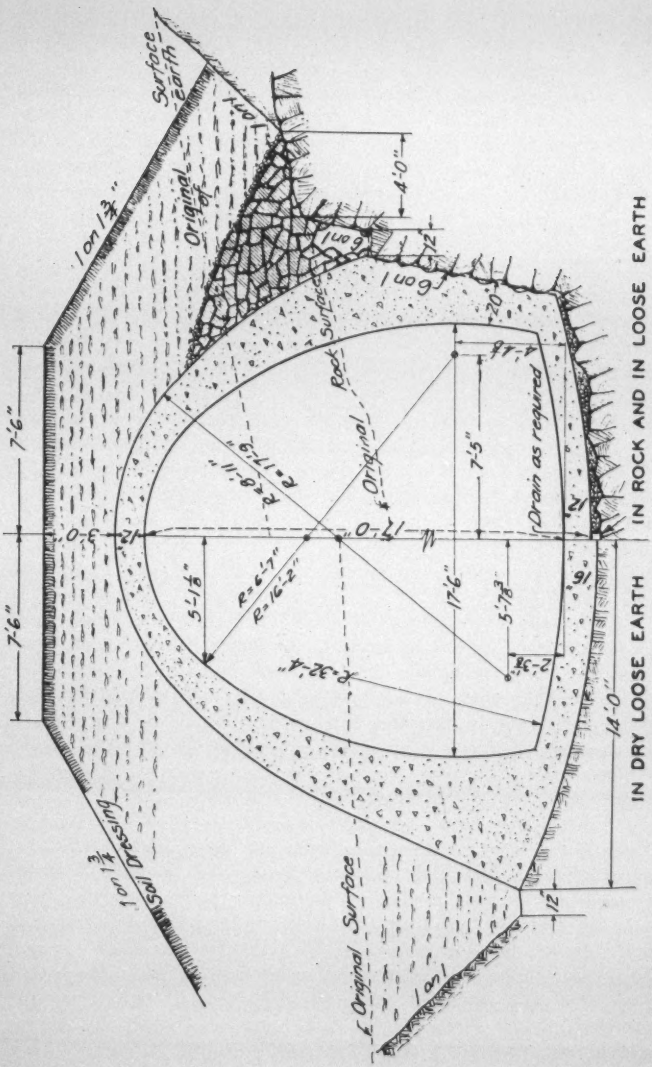


FIG. 14—CATSKILL AQUEDUCT. CUT AND COVER SECTION.

these with the Narrows siphons and with the Staten Island service mains. The reservoir has a depth of 35 ft. The water surface is 228 ft. above sea level.

Catskill Aqueduct. Four distinct types of conduit or aqueduct were adopted to meet the varying physiographic features of the country traversed by the aqueduct from the Catskill mountains to the City. Where the topography and the elevation of the ground permitted, the cut-and-cover type was used (Fig. 14). This type was the least expensive, and was built for a total of 55 miles. The construction consisted of excavating a trench, in the bottom of which a floor or invert of concrete was placed. Resting upon the sides of the invert and bonded to it, the side walls and arch of concrete, without steel reinforcement, were poured between steel forms, to the desired horse-shoe shape. From outside to outside of the masonry required a trench 28 ft. wide or about as wide as between curb to curb of a New York cross-town street. Sufficient earth was taken from the trench to form a protective grassed covering of at least 3 ft. over the concrete. That portion north of Kensico Reservoir is 17 ft. high and 17 ft. 6 in. wide, inside dimensions, and has generally a slope of about 1.1 feet per mile, which is sufficient to allow the desired flow of water to pass by nearly, although not completely, filling the aqueduct. Between Kensico and Hillview Reservoirs the cross-section was enlarged to a height of 17 ft. 6 in. and a width of 18 ft.

Where hills or mountains were encountered, and it would have been impracticable or uneconomical to circumvent them, tunnels were driven and lined throughout with concrete without steel reinforcement. This, the grade-tunnel type (Fig. 15), acts similarly to the cut-and-cover type in that the water flows in it as it would in an open channel. It also is a horse-shoe shape, but of lesser dimensions and steeper slopes. There are 24 of these grade tunnels, aggregating 14 miles; they are 17 ft. high and 13 ft. 4 in. wide inside.

Where valleys were encountered, it was not possible to carry the aqueduct along at the natural elevation or gradient which the water would take, and in such cases, types were adopted which would withstand the bursting pressure produced by placing the aqueduct below the hydraulic gradient. In the larger valleys the pressure tunnel type was used, which consists of a circular tunnel driven deep enough below the valley bed so that the rock will withstand the bursting pressure. The tunnel is connected at either end to the aqueduct by vertical circular shafts also in suitable rock. Tunnels and shafts are lined with concrete without steel reinforcement throughout, and

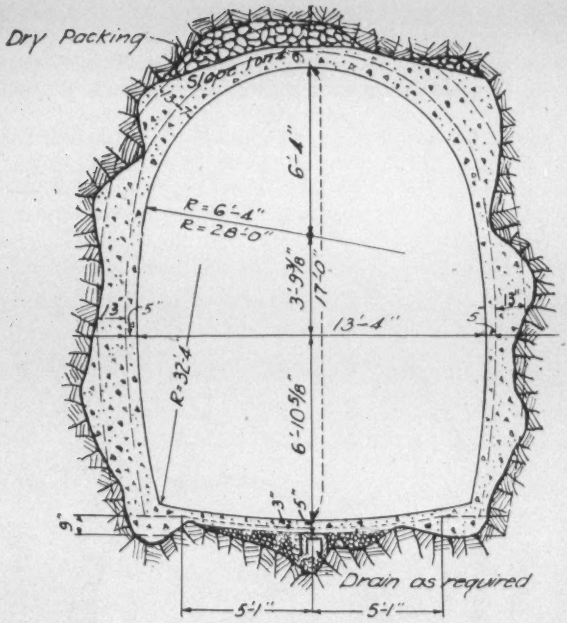


FIG. 15—CATSKILL AQUEDUCT. GRADE TUNNEL.

all seams around the concrete and in the rock are filled by forcing in under pressure thin grout made of Portland cement, fine sand and water. Drainage shafts were constructed so that each pressure tunnel can be unwatered for inspection, cleaning and repair. Besides the end and drainage shafts, other shafts were sunk to aid in excavating and lining the tunnels. These construction shafts were afterwards sealed with deep concrete plugs just above the tunnel and partially refilled, near the top, with rock débris and earth supported on concrete arches across the shaft. There are seven of these pressure tunnels, totaling 17 miles, varying in diameter from 14 ft. to 16 ft. 7 in.

The most important of the valleys to be crossed was that of the Hudson River, where the tunnel was driven in granite rock at a depth of 1,114 ft. below sea level. This 14-ft. tunnel extends from a shaft at Storm King mountain on the west bank to another shaft

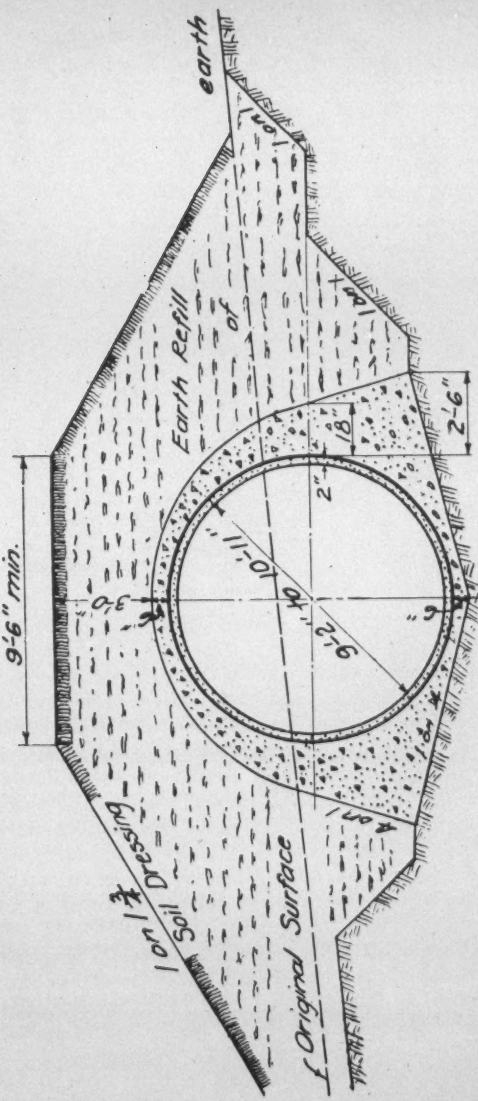


FIG. 16—CATSKILL AQUEDUCT. STEEL PIPE SIPHON IN EARTH. THREE PIPES FOR EACH SIPHON.

on the east side of the river at Breakneck Mountain, a distance of 3,022 ft.

Across the smaller valleys, or where the rock was not suitable for a pressure tunnel, three parallel lines of riveted steel pipe each encased in concrete and lined with two inches of cement mortar, were laid in trenches just below the natural surface and covered with a protective grassed embankment of earth. This is known as the steel-pipe siphon type (Fig. 16), although it is not truly a siphon but rather an inverted siphon. The pipes are from 9 to 11 ft. in diameter and are made of steel plates from 7/16 to ¾ in. in thickness, riveted together. There are fourteen of these siphons, totaling six miles.

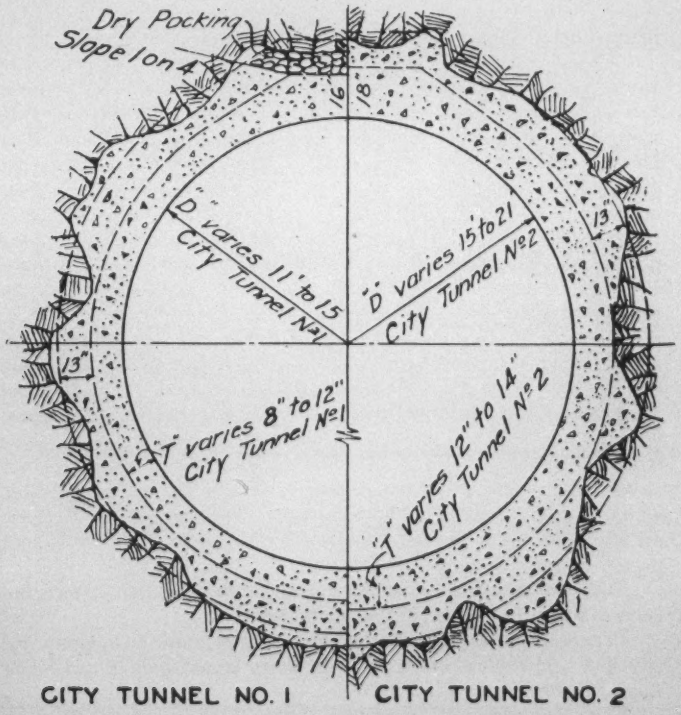


FIG. 17—CITY TUNNELS NO. 1 & NO. 2. PRESSURE TUNNEL.

City Tunnel No. 1. From Hillview Reservoir, Catskill water is delivered into the five boroughs by a circular tunnel in solid rock, reducing in diameter from 15 ft. to 14, 13, 12 and 11 ft. The total length of the tunnel is 18 miles. From two terminal shafts in Brooklyn, steel and cast-iron pipe lines extend into Queens and Richmond, respectively. Two flexible-jointed cast-iron pipes, one 36 in. the other 42 in. in diameter, buried in trenches in the harbor bottom, have been laid across the Narrows to the Staten Island shore, whence a 48-in. cast-iron pipe and a 66-in. steel pipe extend to the Silver Lake Reservoir. The tunnel is at depths of 200 to 750 ft. below the street surface, thus avoiding interference with streets, buildings, subways, sewers and pipes. These depths are necessary, also, to secure a substantial rock covering to withstand the bursting pressure of the water inside, and afford the requisite watertightness. The waterway of the tunnel is lined throughout with Portland cement concrete.

City Tunnel No. 1, which is one of the longest tunnels in the world for carrying water under pressure, or for any other purpose, was constructed from 25 shafts, including the downtake shaft at Hillview Reservoir, about 4,000 ft. apart, located in parks and other places where they interfered very little with traffic. Through twenty-two of these shafts the water is delivered into the street mains. These connections from the tunnel to the mains are made by means of vertical riveted steel pipes (called risers), embedded in concrete in the upper part of each shaft and lined with concrete to prevent corrosion inside. Provision is made for unwatering the tunnel, whenever necessary, for inspection, cleaning or repairs.

Unusual features in connection with the operation of the tunnel are the bronze valves in the shafts, 48 and 72 in. in diameter, and the section valves, 66 in. in diameter, also of bronze. The former are located about 100 ft. below the top of sound rock and are designed to close automatically in case of an important break in the valve chamber. They can also be closed by hand from within the chambers at the shaft tops. The section valves, two in number, are located across the main tunnel, at the bottoms of shafts 13 and 18, and permit the tunnel to be divided into parts and drained in sections without putting it entirely out of commission.

At Shaft 3, at the northerly end of Jerome Park Reservoir, connection was made to the Jerome Park Reservoir.

The cost of the portions of the Catskill Aqueduct within the city limits, including the tunnel, pipe lines, appurtenances and Silver Lake Reservoir, was $23,000,000.

City Tunnel No. 2. A second tunnel, 17 ft. in internal diameter

FIG. 18—CITY TUNNEL NO. 2, 17 FEET IN DIAMETER, DURING CONSTRUCTION.

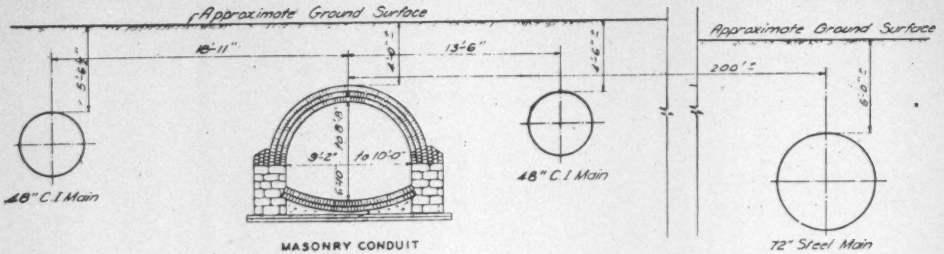
and 20 miles in length, known as City Tunnel No. 2 (Fig. 18), has recently been completed, and was placed in service on March 31, 1936. It extends from Hillview Reservoir through the Bronx, under the East River at Riker's Island, through Queens and Brooklyn, to the intersection of Hicks Street and Hamilton Avenue, connecting with the first City Tunnel at Ft. Greene Park. This tunnel will not only deliver additional water, but will also serve to safeguard the continuity of the supply to the various boroughs. It cost approximately $50,000,000.

Ridgewood System

The drainage area tributary to the Ridgewood system on Long Island extends from the borough limits of Brooklyn easterly approximately to the Suffolk County Line. The watershed is bounded on the south by the marshes and tide waters of Jamaica and Hempstead Bays, and on the north by the ground water summit which, in a general way, follows the surface divide. The area of the watershed is about 168 sq. miles and as at present developed, including three driven-well plants within the limits of the Borough of Brooklyn, may be depended upon for a yield of 115 m.g.d.

The greater part of the watershed is within the broad sandy plain which slopes gently from the hills in the central part of the island southerly to tidewater. The surface soil covering is usually light and very pervious, and ordinarily overlies coarse yellow sands and gravels of glacial origin. Below these occur gray sands and gravels separated by strata of clay of varying thickness and extent which extend to bed rock at a depth of 500 to 1,100 ft. or more. Due to the porous character of the soil, practically all the rainfall is absorbed and passes underground towards the sea; a small portion appears in the form of streams where the surface of the ground dips below the water table.

That part of this watershed to the west of Hempstead is generally known as the old or west watershed; the present sources of supply are Smith's Pond, Pines Pond, Hempstead Pond, Schodack Brook, Hempstead Storage Reservoir, and ten driven-well pumping plants. The supply is collected by a brick conduit of horse-shoe section, about 12 miles long, having a slope of approximately six inches to the mile, extending from Hempstead Pond to the Ridgewood Pumping Station, where all the water is pumped into the Ridgewood Distributing Reservoir; a 72-in. steel pipe line extending the entire length of the watershed was formerly utilized for conveying the delivery of some of the driven-well plants to the Ridgewood Pumping Station, but in



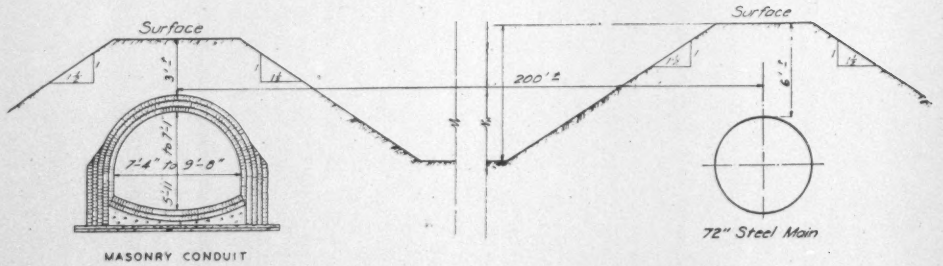


FIG. 19—BROOKLYN CONDUIT AND PIPE LINES.

1925 the section extending westerly from the Milburn Pumping Station was placed under the Brooklyn distribution pressure, and delivers water to Brooklyn, the Rockaways and other sections of Queens Borough (Fig. 19). The brick conduit has a gradually increasing section towards the west, the carrying capacity of the maximum section being 75 m.g.d. The other ponds on this shed (Baisley's, Springfield, Simonson's, Clear Stream, Valley Stream and Watts), the surface waters of which were originally pumped into the main conduit or delivered into it by gravity through branch brick conduits of circular cross-section, have been abandoned, on account of pollution due to increase in population.

The new watershed, adjoining the old on the east, has for its sources of supply five ponds—Milburn, East Meadow, Newbridge, Wantagh and Massapequa—five driven-well plants, and two infiltration galleries. The Milburn and Newbridge Ponds have been abandoned as direct sources of supply. The supply is collected and carried by gravity to the pump well of the Milburn Pumping Station through a brick conduit a little over 7¼ miles long, extending from Massapequa westward to the Milburn Pumping Station, and having a grade of one in ten thousand.

This conduit is of horse-shoe section 5 ft. 11 in. high, and 7 ft. 4 in. wide at its easterly or Massapequa end, with a capacity of 40 m.g.d. The size increases at each supply pond, and at its westerly end at Milburn Pumping Station the section is 6 ft. 11 in. high by 9 ft. 4 in. wide, with a capacity of 60 m.g.d.

The ponds in the east watershed discharge into the conduit which they immediately adjoin on the north, through short sluiceways; the driven-well and infiltration gallery pumping plants are just south of the conduit and discharge into same, or into the 72-in. steel pipe line, through short delivery mains. The two infiltration galleries aggregate six miles in length and yield 30 to 40 m.g.d.; they consist of vitrified tile sewer pipe laid with open joints surrounded with gravel, from 10 to 15 ft. below the normal ground water level.

All the water from the east watershed is pumped at the Milburn Pumping Station where part of the supply is delivered to the 72-in steel pipe line before mentioned, and part through three 48-in. cast-iron pipe lines leading to Ridgewood Pumping Station, where it is repumped. Two of these 48-in. lines formerly extended directly to Ridgewood Pumping Station, being reinforced at Spring Creek by another 48-in. main. In 1927, the three 48-in. pipe lines west of Spring Creek were replaced by a 72-in. reinforced concrete pipe which was made necessary by the construction of Sunrise Highway. These

mains adjoin and are parallel to the old brick conduit for the entire distance west of Smith's Pond. The third 48-in. pipe from Milburn reduces to 36 in. at the efflux chamber of the abandoned Milburn Reservoir and terminates at the old brick conduit at Smith's Pond; by this means the old conduit can be partly utilized for conveying some of the yield of the new watershed.

Queens System

Local municipal sources of supply within the limits of the Borough of Queens are derived from driven wells. All of the local sources in Queens must be pumped, and the city maintains one steam and one electric pumping station, and seven individual electrically operated well stations for this purpose. The Queens system yields about 24 m.g.d. and is used, as needed, to supplement the Catskill supply.

Development of Additional Supply from Long Island

Application was made on February 23, 1932, to the State Water Power and Control Commission for developing an additional supply of 94 m.g.d. from the Long Island watershed in the Counties of Kings, Queens and Nassau to maintain pressures locally in heavy draft periods, and to permit of the substitution of Long Island waters during periods of extreme drought for a portion of the water that normally would be taken from the Catskill watershed. Most of the wells that were to be thus developed would not have been drawn upon for the greater part of the time. In addition to the 94 m.g.d., the application also covered a proposed development of 10 m.g.d. in the Rockaways for an emergency supply.

The State Water Power and Control Commission rejected, with the exception of the Rockaway development, in almost its entirety, the application, the chief reason being the over-development of the subsurface sources, particularly in the westerly portion of the Island.

Richmond System

The Richmond system consists of three driven-well plants located in different parts of the borough. One of these plants consists of five stations driven electrically, each pumping its output into the distribution system. The Richmond system yields about 10 m.g.d. and, since the introduction of Catskill water, has been used chiefly to make up the difference between the capacity of the Catskill conduit to Richmond and the consumption demands within the borough limits. One station electrically operated is used for boosting Catskill water to the high and intermediate services.

Utilization of the Present Sources of Water Supply

As previously stated, the City now has available, in addition to the Catskill supply, all of its older sources, including the Croton, Brooklyn, Queens and Richmond systems.

The sources of supply for the municipal system, and the amounts each may furnish are as follows:

Source of Water Supply	Tributary watershed area Sq. Miles	Quantity estimated to be continuously available based on drought period such as might occur once in 100 years, with a reserve of 25% of total available storage
Schoharie Watershed	314	500
Esopus Watershed	257	
Bronx and Byram Watersheds	22	10
Croton Watershed	375	300
Ridgewood and Brooklyn Borough	Indeterminate	115
Queens Borough	Indeterminate	24
Richmond Borough	Indeterminate	10
	Total	959
PROPOSED DEVELOPMENTS		
East Branch Watershed	370	370
Neversink Watershed	70	70
Rondout Watershed	100	100
Additional wells in Richmond	Indeterminate	10
	Total	550

All of the sources of supply furnish a safe and palatable water. Therefore, when it becomes necessary to furnish additional amounts of water, due to increases in consumption, the available sources are drawn upon in the order of their cost of operation.

Catskill water flows and is delivered to all five boroughs of the city by gravity, the only exception being small areas located on the higher ground.

Catskill water is generally used to the full present capacity of the Catskill aqueduct, because through its greater pressure it constitutes the least expensive of the supplies to operate.

Croton water also flows to the city by gravity, but it is delivered to the boroughs of Manhattan and the Bronx at an elevation which is much lower than that of the Catskill supply, and the amount that can be used without pumping is limited to the demands in portions of Manhattan and the Bronx lying in general below El. 40 ft. The demand in these portions averages about 130 m.g.d. All Croton water that is used on higher ground must first be pumped to give it ade-

quate pressure. The department maintains three steam and one electrically operated pumping stations for this purpose, having a combined capacity of about 160 m.g.d.

The City maintains all of its old sources of supply and retains a reserve force to permit the prompt starting up of some of the stations in case of emergency. The pumped supplies, being the most expensive to use, are drawn upon as the gravity supplies are utilized to their greatest permissible extent.

Quality of Water

A great safeguard which the City possesses is the extent of storage on its up-state watersheds; the long period of sedimentation afforded by the large storage reservoirs serves to reduce the bacterial content and turbidity. For the sanitary protection of these reservoirs, the City acquired a marginal strip averaging 1000 ft. in width around the Schoharie and Ashokan reservoirs, 500 ft. around Kensico Reservoir and 300 ft. around the Croton reservoirs and along the streams emptying into them.

An inspectional force under a sanitary expert patrols the watersheds to detect and abate sources of contamination and to see to it that the Department's sanitary rules and regulations are observed.

All water is treated with chlorine. The Croton supply is so treated at the Croton Lake Gate House and again at Dunwoodie, Yonkers, and at the 135th Street Gatehouse. On the Croton watershed, the Peach Lake effluent and Tonetta Brook are treated at Brewster, Katonah Brook at Katonah, Kisco River at Mt. Kisco, St. Mary's Brook at Bedford Hills, Kilday Brook at Bedford, the outlet of Lake Glenieda at Carmel and the sewage at the Brewster and Mt. Kisco plants. The Catskill supply is treated as it leaves the Ashokan Reservoir, at Kensico Reservoir and again at the Hillview Reservoir downtake chambers. The Long Island supply is treated at Milburn Pumping Station, Smith Pond, Hook Creek and Ridgewood pumping stations. At the Brooklyn, Queens and Richmond driven-well stations the water is also chlorinated. There are altogether some 40 city-owned chlorinating plants and 80 privately operated plants at which chlorine may be applied to the water supplied to the city consumers. A very high degree of disinfection has been uniformly secured at all of these plants. The typhoid fever death rate has been progressively reduced. It was but 0.5 per 100,000 of population in 1935. These deaths were not due to the use of impure water, but rather to infection acquired: by bathing; from carriers; by the consumption of oysters, milk, uncooked vegetables and ice cream; or outside of the city limits.

All Catskill water is aerated to free it from gases which produce unpleasant odor or taste. These aerators, each consisting of some 1600 nozzles, are installed at the Ashokan and Kensico reservoirs.

Microscopic organisms which develop in the reservoirs and at times impart an unpleasant taste and odor to the water, are destroyed by treatment with copper sulphate and by chlorination.

To reduce the turbidity of the Catskill supply when necessary, alum and lime are added at a coagulating plant at Pleasantville, about 30 minutes' flow above the influent to Kensico Reservoir; the floc entangling the turbidity, settles out in Kensico Reservoir before the water reaches the effluent gate house.

The department operates the sewage disposal plants of the villages of Brewster, in Putnam County, Mt. Kisco, in Westchester County, Chichester and Pine Hill in Ulster County, Tannersville in Greene County and Grand Gorge in Delaware County; it makes periodic tests to control the operation of the disposal plants of private institutions in the watershed and passes upon plans for all private disposal plants.

Open gravity-type rapid sand filters are used to remove iron from the well waters at the Springfield, Jameco and Rockaway Park pumping stations and by means of pressure filters at the Flushing station.

The forestation started in the Croton watershed in 1912 by planting three- and four-year old evergreen transplants along the shores of reservoirs and adjacent to public roads has been continued in this as well as in the Catskill, Bronx and Byram watersheds. These trees in addition to beautifying the general landscape, provide a dust screen, prevent erosion and serve to equalize the run-off.

New mains are sterilized and are not placed into service until laboratory analyses show them to be clean. Cross-connections, or a connection from any other source of supply to any piping supplied by city water, are forbidden.

At three laboratories, daily bacteriological examinations are made of samples of water taken at different points. Additional samples from sources of supply which do not require daily investigation result in the laboratories examining over 26,000 samples during the year. In case any portion of the supply is shown to be unsatisfactory, either its use is discontinued or the objectionable conditions are ascertained and remedied. The laboratories in question are well equipped with modern apparatus and are located respectively, at Mount Prospect Reservoir, Brooklyn, at Mount Kisco, Croton watershed and at the Ashokan Gatehouse, Catskill watershed.

The question whether or not the water supply of New York City

should be filtered was considered in 1910, the then responsible authorities reaching the conclusion that it was not necessary to do so at that time. With the growth of the communities on the watersheds and under an insistent public demand the subject will, in due course, undoubtedly again receive attention.

Distribution Systems

The distribution systems in the various boroughs are divided into independent services or zones, with three or more such zones in each borough. The areas of these zones are determined chiefly by the local topography. The ground elevation in the city varies from a few feet above sea level along the water front to 430 ft. at Todt Hill in the Borough of Richmond; this, incidentally, is the highest point on the Atlantic coast south of Maine. The highest ground elevations in the other boroughs are: Manhattan, 267 ft.; Bronx, 284 ft.; Brooklyn, 210 ft.; and Queens, 266 ft. above tide.

The average pressure at hydrants in the different service zones in the city ranges from 35 lb. per sq. in. in the Manhattan low-service area to 80 lb. per sq. in. in the Richmond high-service area. The average pressure in the city is approximately 55 lb. per sq. in., which is adequate for supplying water to the top floor of an eight-story building.

To provide for the hourly fluctuations in demand, the maximum hourly rate during the morning and evening hours being two to three times that shortly after midnight, as well as a limited amount of storage within the city limits to meet emergencies, there are five principal distributing reservoirs. The Hillview Reservoir just north of the city line and the Silver Lake Reservoir in the Borough of Richmond, have been described under the "Catskill System".

Jerome Park Reservoir in the borough of the Bronx is an uncovered concrete-lined basin formed by earthen embankments and natural ground, excepting the easterly side which is a masonry structure originally intended for a division wall to divide the reservoir into the east and west basin, the former never having been built. The "division wall" carries the Old Croton Aqueduct throughout its entire length as well as a branch of the New Croton Aqueduct to its southerly end where it discharges into the reservoir. The main New Croton Aqueduct crosses the reservoir in a tunnel about 100 ft. below the surface and continues to the 135th Street Gate House in Manhattan. The flow into and out of the reservoir is controlled by three gate chambers.

The gate house at the northerly end of the reservoir at the

division wall controls the flow through a short stretch of tunnel leading to Shaft 3 of City Tunnel No. 1 of the Catskill System. The arrangement of piping in the chamber permits either the delivery of Catskill water into the reservoir or the pumping of Croton water from the reservoir into City Tunnel No. 1. This pumping is by means of three electrically-driven pumps at the so-called Mosholu Pumping Station, installed in the shaft chamber, each pump of a capacity of 20 m.g.d.

The present reservoir with a capacity of approximately 800 m.g. at the spillway elevation of 135.50 ft. was filled in 1905. Work at the east basin was suspended pending decision of the question of filtering the Croton supply. The filtration plant was to have occupied the area intended for the east basin but in 1912 the entire project was abandoned and the lands were released by the department in 1917. The site is now occupied by educational buildings, subway yard and other structures.

The new Central Park Reservoir in Manhattan is an open basin completed in 1862 when the old Croton aqueduct was the only aqueduct supplying water to the City of New York. It was constructed "to keep an available supply of water in case a break should occur in the aqueduct making it necessary to shut off the water for examination and repairs." At the present time it still receives water from the Old Croton Aqueduct and in addition it is supplied from the New Croton Aqueduct by means of five 48-in. pipe lines from the 135th Street Gatehouse. The reservoir is now being used as an equalizing and distributing reservoir for the low-service areas in Manhattan; it holds 1017 m.g. at the spillway elevation of 119.36 ft.

The entire supply of Croton water delivered to the city through the Croton aqueducts is distributed from Jerome Park Reservoir in the Bronx and from Central Park Reservoir and the 135th Street Gatehouse in Manhattan. A number of widely scattered areas of low elevation, generally below 40 ft., are supplied by gravity from these distributing points. This gravity supply amounts to about one-half of the total available Croton supply; the remainder of the Croton supply is pumped at the 98th Street and the 179th Street pumping stations in Manhattan and at the Mosholu and Jerome Avenue pumping stations in the Bronx to reach the higher elevations.

The Catskill supply, which extends to all five boroughs, is distributed from the riser shafts of City Tunnel No. 1 and No. 2. The Catskill gradients are sufficiently high to reach all but the highest elevations in Manhattan and Richmond. The pressures are regulated at the distributing points, if necessary, to maintain the desired pres-

sures in the different service zones. In the services supplied with both Catskill water and water pumped from some other sources of supply, the Catskill pressure is regulated to accommodate the gradient of the pumped supply.

The supplies from the Ridgewood, Brooklyn and Queens Borough systems, which are obtained chiefly from sub-surface sources, must be pumped. Part of the supply is delivered directly into the Ridgewood Reservoir, which also receives water from the Catskill System, and is used as an equalizing reservoir for the Brooklyn low-service. This reservoir, located on Cypress Hills, consists of three basins with an aggregate capacity of 304 m.g. at the high-water elevation of 172.54 ft. Each basin has a puddled bottom and sloping sides paved with stones. The first two basins of half the total capacity were completed in 1858 and the third in 1891.

The pipes used for distributing the water supply range in size from 4 to 72 in. At the close of 1935, the total length of steel and cast-iron pipe in service amounted to 4,624 miles as given in detail in Table 4. With the improved protective coatings developed, the department adopted in 1926, in order to reduce the considerable damage from flood resulting from breaks in cast-iron trunk mains, the policy of installing water mains 30-in. and larger of steel with a minimum thickness of plate of ½-in.

The minimum size of cast-iron pipe used for extensions is 12 in. in congested sections and 8 in. elsewhere. To overcome the excessive tuberculation caused by the soft and "active" Catskill water, all cast-iron pipe since 1929 has been furnished with an ⅛-in. interior cement mortar lining, coated with a cold application of asphalt paint (without effect either upon the taste or odor of the water) to retard or entirely prevent the leaching of the cement.

Gate valves are located near street intersections, and the arrangement provides in general for convenient shut-off sections. A standard double-disc valve, opening clockwise, adopted some 25 years ago, predominates. The valves in the Catskill shafts are operated by small water motors; some of the large control valves in the gate houses of the distributing reservoirs are motor or hydraulically operated. At the close of 1935, a total of 122,806 valves, ranging in size from 4 to 48 in., was in use.

Hydrants are of the double-nozzle type, and most of the 70,957 in use at the end of 1935 were of the New York standard, which has a 6-in. gated connection with the main and a 7½-in barrel with one 2½-in and one 4½-in. outlet.

Fifteen repair companies are maintained for keeping the valves

and hydrants in good operating condition, to repair breaks in water mains, and stop reported leaks such as may be caused by loose joints, abandoned taps, service pipes, hydrants, and valves. During the past ten years, an average of over 20,000 leaks in the distribution system have been stopped annually by these repair companies. In each borough, an emergency force of, at least, one gang is on duty at all hours.

The Department determines the locations not only of water mains, but of all other sub-surface structures (such as electrical conduits, gas mains, steam pipes, and pneumatic tubes) except sewers and rapid transit tunnels. This enables the Department to provide for ready access to water mains for repairs and connections, to protect the water mains from excessive loads of other structures crossing them, and to ensure the reservation of adequate space for the installation of future mains.

High-Pressure Fire Service

The Department of Water Supply, Gas and Electricity also operates in portions of Manhattan and Brooklyn and at Coney Island a special service by means of a high-pressure fire system to which no connections to buildings are permitted and which is used exclusively for fire-fighting purposes.

The Manhattan system was first used in July, 1908. It covers approximately 3700 acres in lower Manhattan where it protects the valuable business and industrial centers. The Brooklyn system, which was placed in service in November 1908, protects the important manufacturing, business and water-front section lying between 39th Street and the Navy Yard, covering approximately 3100 acres. The Coney Island system covers 900 acres.

One of the Manhattan pumping stations is at Oliver and South streets and the other at Gansevoort and West streets, each with a capacity of 18,000 g.p.m. at 300 lb. per sq. in., with increased capacities at lower pressures. There are two similar stations in Brooklyn, located respectively at Furman and Joralemon streets and at Willoughby and St. Edward streets, the former having a capacity of 15,000 g.p.m. and the latter, 9,000 g.p.m. at 300 lb. per sq. in. The Coney Island Station is at West 12th Street and Neptune Avenue. It will shortly be replaced by a modern, completely fireproof structure, which is being erected at Neptune Avenue and West 25th Street, and which will increase the pressure now available by 40 lb. per sq. in. and will more than triple the present pumping capacity. The capacity of this station will be 13,500 g.p.m. at 200 lb. per sq. in. pressure.

The length of the high-pressure fire-service mains in Manhattan is 128 miles, 8 to 24 in- in diameter, and in Brooklyn, 50 miles, 8 to 20 in. in diameter. The lower East Side of the Manhattan system is arranged so that it may be divided instantaneously into two independent systems; when so divided, each system serves the alternate cross streets and the alternate streets running north and south. In case of a break only one system would be affected, as the other would be shut off from it immediately by valves electrically operated from the pumping stations.

The high-pressure fire-service stations are operated through high-voltage current furnished in Manhattan by the New York Edison Company and in Brooklyn proper and the new Coney Island Station, by the Edison Electric Illuminating Company. The old Coney Island engines are gas-driven. Upon the request of the Fire Department, the pressure can be increased up to 300 lb. per sq. in. At Coney Island, the limit of pressure will be 200 lb. per sq. in. When an alarm is received, pressure is furnished throughout each of the systems within the period of a minute.

Salt water can be used in this system, but its use is not contemplated in Manhattan or Brooklyn, unless the fresh-water supply were to fail, which has never yet occurred. At Coney Island, salt water is used in conjunction with fresh water.

Consumption and Waste of Water

The daily aggregate consumption of water within Greater New York averaged 950 m.g.d. during 1935, including the 60 m.g.d. furnished by the private water companies of Brooklyn and Queens. This corresponded to a per capita consumption of 126.1 g.p.d. In addition to the foregoing, the municipality supplied 19.5 m.g.d. to communities outside of the city.

For the last twenty years, the Water Department has maintained a force of trained men under engineering supervision to trace the source of water flows entering basements, electric conduits, subways, etc., in the most difficult cases where the shop repair forces were unable to locate the source of trouble. This force operated in the boroughs of Manhattan and the Bronx, where rock fill exists under many streets through which water from leaks readily escapes. The average leakage located and stopped yearly has been about 10 m.g.d. From the experience of this force, it has been known that many leaks exist that are not causing complaint and are not observable, but during the years of plentiful supply, the force (consisting since 1918

of but four field parties to cover the two boroughs) was insufficient to do more than take care of such complaint work.

The drought of 1930 brought the total available supply far below the average of previous years, dangerously close to the 930 m.g.d. average consumption of that year, and forcibly emphasized the necessity for utilizing all possible measures for rapid reduction of waste and conservation of the supply.

During 1930, an additional force of four field parties was approved to make systematic surveys and searches for those hidden underground leaks that are not causing complaints. This work was confined to the boroughs of Manhattan and the Bronx, where the subsurface conditions as described are most favorable to the accumulation of such leakage.

In 1931, this special force covered those two boroughs with a "preliminary survey" aiming to locate as rapidly as possible the largest leaks of this character, and during the year stopped leakage totaling 26 m.g.d. The regular complaint force during the same period stopped, in addition, a total leakage of 14 m.g.d.

In 1932, the special force was employed on a "re-survey" including tests on the individual house-service pipes to locate the smaller main and service leaks. The total leakage stopped was 25 m.g.d. The cost of the underground waste work is about $3.00 per million gallons of water saved, which is only a small fraction of the cost of delivering water to the city. The work has been continued since with the same successful results.

In addition to the surveys for the suppression of leakage from underground mains and service pipes, a house-to-house survey for the suppression of leakage from plumbing fixtures in some 580,000 unmetered buildings is in progress. The aggregate waste within buildings, where the services are not metered, is conceded to be a very large amount. The house-to-house inspection was started in the spring of 1934 with a corps of 270 temporary Emergency Relief Administration employees. On a first survey made by these employees, about 80% of the unmetered buildings were examined, with 400,000 fixtures leaking out of a total of 12,500,000. It is estimated that in 1935, a reduction of 60 m.g.d. was effected and that by repeated inspections covering the city once a year, it might be possible to reduce the consumption 90 m.g.d. A new and better qualified force of inspectors furnished by the U. S. Works Progress Administration was organized during the latter part of 1935 and is continuing this work at the present time. On this second survey, in addition to reporting leaky fixtures, the force reports the different items upon which frontage

rates are based, such as the number of stories, families, baths, etc., in order to check and revise, if necessary, the annual frontage charges. On this second survey, all reports of leaky fixtures are followed up to see that they are promptly repaired by the owners of the property, and if they are not repaired, a penalty of $2.00 is imposed, which becomes a lien upon the property, each time subsequent inspection shows the fixture or fixtures still leaking.

Private Water Companies

Some 750,000 citizens residing in Brooklyn and Queens and consuming about 60 m.g.d. are still dependent upon private water companies for water. All of these companies draw their supplies from driven wells. The one located within the Borough of Brooklyn is the New York Water Service Corporation (Flatbush Plant), serving the Twenty-ninth Ward (Flatbush). In the Borough of Queens, the Jamaica Water Supply Company and the New York Water Service Corporation (Woodhaven Plant) furnish water for the Fourth Ward. In addition, the Broad Channel Corporation supplies a small amount of water from local driven-wells to Broad Channel Island. The Flatbush Water Works, which originally supplied the Twenty-ninth Ward of Brooklyn, and which was succeeded in 1926 by the New York Water Service Corporation, was originally incorporated on February 14, 1881, and had an exclusive franchise for supplying that territory with water. The Woodhaven Water Supply Company, which supplied the Woodhaven or westerly section of the Fourth Ward of Queens, and was succeeded in 1926 by the New York Water Service Corporation, was incorporated on February 28, 1888. The Jamaica Water Supply Company, which supplies the easterly portion of the Fourth Ward of Queens, was incorporated on April 21, 1887.

The average quantity of water supplied by the private water companies during 1935 was as follows:

New York Water Service Corp. (Flatbush Plant)	26.1 m.g.d
Urban Water Supply Co. (Consumers supplied by City after Nov. 1, 1935)	0.3 m.g.d.
Jamaica Water Supply Co.	24.2 m.g.d.
New York Water Service Corp. (Woodhaven Plant)	7.8 m.g.d
Broad Channel Corp.	0 m.g.d.
Total	58.4 m.g.d.

The private companies are under the general superintendence, regulation and control of the Commissioner of Water Supply, Gas and Electricity.

Supply to Communities Outside of New York City

Under Chapter 726 of the Laws of 1905 "Any village or town in the County of Putnam, or a corporation or person or persons authorized by or in pursuance of law to establish therein a water works system for supplying such village or town and the inhabitants thereof with water, may connect its or their water mains and pipes with the lakes, streams, reservoirs, aqueducts, water pipes and conduits of the City of New York now or hereafter located in such county and take water therefrom for supplying such village or town and the inhabitants thereof with water." The amount is limited by the population supplied and the per capita consumption of New York City; the price is to be agreed upon with the Board of Estimate and Apportionment of New York City or fixed by the Supreme Court upon application by such applicants.

Chapter 350 of the Laws of 1909 granted similar rights to municipalities in Nassau County, at prices to be fixed by the Commissioner of Water Supply, Gas and Electricity, which, however, were not to exceed the Brooklyn rates.

Under Chapter 601 of the Laws of 1916, similar privileges were granted in the County of Westchester to municipal corporations, and at New York City rates. Application need only be made to the Commissioner of Water Supply, Gas and Electricity.

Under Chapter 525 of the Laws of 1928, it is "Lawful for any of the municipal corporations or water districts in the Counties of Ulster, Greene, Delaware, Schoharie, Sullivan, Orange, Westchester and Putnam, to take and receive from any of the reservoirs, aqueducts, conduits, streams or pipes of the City of New York, a supply of water for the uses and purposes of said municipal corporations or water districts. . . ." The price is to be agreed upon between the Commissioner of Water Supply, Gas and Electricity and the municipal corporation or water district authorities or, upon application by either party, by the State Water Power and Control Commission. Rates are to be based upon the actual cost to the City of New York after deducting fixed and operating charges upon the distribution and delivery system within the city limits; such charges are not to exceed the New York City rates and are subject to review by the Supreme Court. Up to December 1, 1938, these charges have been fixed at 75 cents per 1000 cu. ft. of Catskill water and 50 cents per 1000 cu. ft. of Croton water.

Quite a large number of communities have taken advantage of these privileges for securing their entire supply or to augment their supply in periods of emergency.

Sing Sing Prison in the village of Ossining is furnished with a supply of Croton water through a connection to the Old Croton Aqueduct at Spring Street under an Act of Legislature in 1861 (Chapter 282); the price paid the city is 2½ cents per 100 cu. ft.

The total amount of water supplied in 1935 to these outside communities and institutions averaged 19.5 m.g.d.

Water Revenue

The city's water revenue is established through what is known as the Bureau of Water Register. The functions of the Bureau consist in the establishment of revenue from the service, sale, or use of water, and of miscellaneous charges arising therefrom.

In addition, the Bureau supervises the work incidental to the installation of meters, prevention of unnecessary waste of water, and has general supervision over the use of water.

Charges for water on an annual basis, meter registry, costs for installation and repair of meters, and the expense of providing meter glasses are duly transmitted to the Bureau of City Collections, Department of Finance, for rendering of the necessary bills. Such charges are now collected by said Bureau.

Charges for unmetered water furnished in connection with the erection or alteration of buildings require that a permit be obtained and payment made therefor on the basis of the quantity of water to be used as figured from plans on file in the Bureau of Buildings. Where water has been used without permit having been obtained, bills are rendered by the Bureau of Water Register, and if not paid by the end of the month succeeding that in which the bills are rendered, are transmitted to the Bureau of City Collections for entry on their records and collection.

The collections at present made by the Bureau, acting as the representative of the Bureau of City Collections, represent charges for unmetered water used in the erection or alteration of buildings, use of water by vessels which take water from the various shipping hydrants, the use of water for washing streets, sidewalks, areaways, steps, buildings, or other places or things where the regular hose permit is applied for and payment made at the rate of $7.50 per season, and water used by contractors engaged in street repairs, paving, building of sewers, subways and other public works.

Further miscellaneous revenues are established and collected by the Bureau from the following sources: insertion of taps and plugs in water mains, shutting off taps, locating taps, meter testing, fire-flow test, sale of ashes, sale of grass, sale of old material, repairs to lamp-

posts, pole licenses and rentals, electricians' licenses, subpoena fees, rental for use of City property, inspection of material, and such other miscellaneous income as might arise in connection with the activities of the department.

All water charges are established by joint action of the Board of Aldermen and the Commissioner of this Department.

At the close of 1935, there were 586,363 accounts, of which 423,903 were what are known as frontage, and 162,460, as meter accounts. It is estimated that about 24% of the water supply of the City is metered.

Frontage rates vary from $6 for a one-story building 16 ft. wide to $21 for a one-story building 50 ft. wide. To these rates, $3 is added for each 10 ft. in excess of 50 of frontage and $1.50 for each story above the first. The primary frontage rate is predicated upon the building being occupied by one family, containing one bath and one water closet. For each additional bath, $4.50 per annum is added; for each additional water closet $3 per annum and for each additional apartment or family $1.50 per annum.

These constitute the major portion of the revenues derived on an annual basis. There are other miscellaneous charges which contribute only a small portion of the frontage revenue.

Under existing laws, the Commissioner of the Department has authority to cause water meters to be installed in business premises only. The law, however, gives the owner of a lot or premises the right to apply for a meter. At present, substantially all water used for commercial and industrial purposes is metered. Meter rates are 15 cents per 100 cu. ft.

The so-called frontage rate and most of the miscellaneous rates, as originally established in the City of New York, remained unchanged from 1851 to the end of 1933. The meter rates remained the same from 1870 to the end of 1933. Beginning with January 1, 1934, all rates were increased a flat 50%.

Financial

The municipal water supply system of the entire City represents, up to January 1, 1936, an investment of $513,278,000. The bonds outstanding on the same date amounted to $375,583,368.10. The cost of operation and maintenance of the system during 1935 was $7,303,892.07. Interest and sinking fund charges amount to approximately $19,587,104.85. The total revenue from the sale of water in 1935 amounted to $36,811,843.90.

Administrative Officers

Col. Thomas W. Hammond	Commissioner of Water Supply, Gas and Electricity
John E. Eastmond	Deputy Commissioner, Borough of Brooklyn
Herman Forster	Deputy Commissioner, Borough of the Bronx
William H. Correale	Deputy Commissioner, Borough of Queens
Charles G. Keutgen	Deputy Commissioner, Borough of Richmond

Table 1—Storage Reservoirs in Watersheds

NAME	YEAR FIRST PLACED IN SERVICE	ELEVATION OF SPILLWAY—FEET*	STORAGE WITH FLASHBOARDS—MILLION GALLONS
Catskill Watershed			
Ashokan	1915	587 (East Basin) 590 (West Basin)	130,428
Kensico	1915	357	30,573
Schoharie	1926	1130	19,583
Croton Watershed			
Boyd's Corners	1873	580	1,696
Middle Branch	1878	371	4,145
East Branch	1891	416	5,243
Bog Brook	1891	416	4,400
West Branch	1895	502	10,427
Amawalk	1897	399	7,070
Croton Falls	1911	309	14,839
Croton Falls Diverting	1911	309	888
Titicus	1893	324	7,599
Cross River	1908	329	10,923
Muscoot	1905	199	5,705
New Croton	1905	201	28,110
Lake Mahopac	1870	659	575
Lake Kirk	1870	582	565
Lake Gleneida	1870	504	165
Lake Gilead	1870	496	380
Barret's Pond	1870	778	170
White Pond	1896	830	200
		Total	103,100
Bronx and Byram Watersheds			
Byram	1897	451	925
Wampus	1897	409	87
		Total	1,012
Long Island Watershed			
Hempstead	1879	30	880
Ponds—Hempstead	1862	—	27
Pines	1862	—	9
Smiths	1873	—	42
East Meadow	1892	—	19
Wantagh	1892	—	44
Massapequa	1891	—	17
		Total	1,038

*Elevations refer to mean sea level at Sandy Hook

TABLE 2—MAIN AQUEDUCTS AND PIPE LINES

DESCRIPTION	LIMITS	TYPE	LENGTH—MILES	RATED CAPACITY—m.g.d.
Catskill Aqueduct (Shandaken Tunnel)	Schoharie Reservoir to Ashokan Reservoir	Grade tunnel	18	650
Catskill Aqueduct	Ashokan Reservoir to Hillview Reservoir	Cut-and-cover Grade tunnel Pressure tunnel Steel pipe siphon	55 14 17 6	600
Catskill Aqueduct (City Tunnel No. 1)	Hillview Reservoir to Manh., Bronx, and Brooklyn	Pressure tunnel	18	1000
Catskill Aqueduct (City Tunnel No. 2)	Hillview Reservoir to Bronx, Queens, and Brooklyn	Pressure tunnel	20	1000
New Croton Aqueduct	Old Croton Dam to 135th St. Gatehouse	Grade tunnel Cut-and-cover Pressure tunnel	22.5 1.1 7	285*
Old Croton Aqueduct	New Croton Dam to Central Park Reservoir	Cut-and-cover Grade tunnel C. I. and steel pipe	33 2 3	90**
Bronx Pipe Line	Kensico Res. to W'msbridge Res.	Cast-iron pipe	15.2	20
Long Island Brick Conduits	Massapequa Pond to Milburn Pumping Station	Cut-and-cover	7.3	59
	Hempstead Pond to Spring Creek	Cut-and-cover	12.4	76
Long Island 72-in. Steel Pipe	Suffolk Co. Line to Pitkin Avenue, Brooklyn		23.4	57
Long Island Cast-Iron Pipes	Milburn P.S. to Spring Creek	Two 48-in. pipes	14	50
	Milburn P.S. to Old Milburn Res. Efflux.	48-in. pipe	1.6	25
	Old Milburn Res. Efflux. to Smith's Pond	36-in. pipe	1.4	14
	Spring Creek to Ridgewood P.S.	60-in. pipe	0.6	25
	Pitkin Avenue, Brooklyn, to Ridgewood P.S.	48-in. pipe	0.7	25

*South of Jerome Park Reservoir 250 m.g.d.
**Because of needed repairs present capacity limited to 45 m.g.d.

TABLE 3—DISTRIBUTION RESERVOIRS AND STANDPIPES

BOROUGH	NAME	NORMAL WATER LEVEL ELEVATION—FEET	STORAGE—MILLION GALLONS
	*Hillview Reservoir	295	929
Manhattan	Central Park Reservoir	119	1021
	High Bridge Standpipe	336	...
Bronx	Jerome Park Reservoir	134	773
	Jerome Avenue Standpipe	317	...
Brooklyn	Ridgewood Reservoir (3 basins)	172	300
	Mt. Prospect Reservoir	200	19
Queens	Flushing Standpipe	224	0.8
Municipal	College Point Standpipe	195	0.9
Richmond	Silver Lake Reservoir	228	438
	Clove Reservoir	254	2.7
	Grimes Hill Standpipe	453	0.2
	Tottenville Standpipe	51	0.1

*North of City Line

TABLE 4—DISTRIBUTING MAINS IN USE AT END OF 1935

MATERIAL	DIAMETER—INCHES	LENGTH—FEET
Steel	72	88,194
	66	55,637
	60	59,691
	48	124,218
	36	43,573
	30	27,256
	24	568
	20	2,249
	12	580
	8	985
	6	215
	Total	403,166
Cast Iron	60	4,060
	48	563,937
	42	12,874
	36	444,346
	30	268,801
	24	250,244
	20	1,349,996
	16	658,167
	14	37,066
	12	4,960,344
	10	157,439
	8	8,135,413
	6	6,731,309
	4	437,980
	Total	24,011,976
Galvanized Wrought Iron	3	25,895
	2½	10,360
	2	281,841
	1½	5,983
	1	1,823
	¾	3,340
	Total	329,242
	Grand total (feet)	24,744,384
	Grand total (miles)	4,686.43

TABLE 5—POPULATION AND CONSUMPTION OF WATER IN NEW YORK CITY
PER CAPITA CONSUMPTION EXPRESSED IN GALLONS DAILY; OTHER FIGURES IN MILLION GALLONS DAILY

Year	Population	City Consumption			Per Capita	SUPPLIED BY CITY TO COMMUNITIES OUTSIDE OF CITY	TOTAL CONSUMPTION FROM MUNICIPAL SOURCES
		Municipal	Private Companies	Total			
1898	3,272,418	325.0	23.1	348.1	106.4	*	325.4
1899	3,356,722	349.7	24.0	373.7	111.3	*	350.1
1900	3,446,042	370.4	22.0	392.4	113.9	*	370.8
1901	3,554,079	376.5	23.6	400.1	112.6	*	376.9
1902	3,665,825	387.1	25.1	412.2	112.4	*	387.5
1903	3,781,423	397.6	25.7	423.3	111.9	*	398.0
1904	3,901,023	421.2	27.9	449.1	115.1	*	421.6
1905	4,025,742	444.4	29.0	473.4	117.6	*	444.8
1906	4,166,556	461.8	33.4	495.2	118.9	*	462.2
1907	4,314,237	477.4	35.6	513.0	118.9	*	477.8
1908	4,469,248	480.0	38.6	518.6	116.0	*	480.4
1909	4,632,078	480.6	32.1	512.7	110.7	*	481.0
1910	4,785,190	495.6	32.9	528.5	110.4	*	496.0
1911	4,873,069	461.2	33.2	494.4	101.5	*	461.6
1912	4,960,948	469.4	35.6	505.0	101.8	*	469.8
1913	5.048,827	463.6	35.5	499.1	98.9	*	464.0
1914	5,136,706	507.5	36.9	544.4	106.0	*	507.9
1915	5,224,585	494.6	33.6	528.2	101.1	*	495.0
1916	5,312,464	526.9	39.3	566.2	106.6	*	527.3
1917	5,400,343	545.0	39.6	584.6	108.3	1.0†	546.0
1918	5,488,222	616.0	43.2	659.2	120.1	3.0†	619.0
1919	5,576,101	618.9	41.3	660.2	118.4	0.6†	619.5
1920	5,683,765	689.9	45.0	734.9	129.3	0.4	690.3
1921	5,811,549	684.7	46.6	731.3	125.8	0.7	685.4
1922	5,939,333	703.3	39.2	742.5	125.0	0.6	703.9
1923	6,067,117	723.3	38.3	761.6	125.5	4.1	727.4
1924	6,195,251	738.3	41.9	780.2	125.9	4.0	742.3
1925	6,323,035	794.4	45.2	839.6	132.8	6.7	801.1
1926	6,450,819	814.5	48.8	863.3	133.8	9.0	823.5
1927	6,578,603	816.6	51.5	868.1	132.0	8.0	824.6
1928	6,706,737	825.2	52.6	877.8	130.9	10.7	835.9
1929	6,834,521	883.5	60.2	943.7	138.1	19.0	902.5
1930	6,962,305	920.8	64.5	985.3	141.5	21.5	942.3
1931	7,077,000	883.4	57.2	940.6	132.9	20.6	904.0
1932	7,192,000	877.6	58.1	935.7	130.1	21.7	899.3
1933	7,306,000	880.7	57.8	938.5	128.5	16.8	897.5
1934	7,421,000	902.2	58.5	960.7	129.5	17.0	919.2
1935	7,536,000	891.6	58.5	950.1	126.1	19.3	910.9

*Not tabulated; probably did not exceed 0.4 m.g.d.
†Approximate values.

CALCULATION OF CHEMICAL DOSAGES REQUIRED FOR THE PREVENTION OF CORROSION

BY EDWARD W. MOORE*

[*Received July 25, 1938.*]

Recent water works literature indicates a rather general acceptance of the idea that a water saturated with respect to calcium carbonate is a non-corrosive water. There is some evidence, notably that given by Gilcreas[1] in a recent paper, that certain waters not saturated with calcium carbonate may also be non-corrosive, but no very strong evidence has been offered of corrosive action on the part of saturated waters. Various forms of chemical treatment are used to produce calcium carbonate saturation, notably treatment with lime, or with soda ash, or by passage of the water through beds of marble or limestone.

The standard test for determining whether or not a water is saturated with respect to calcium carbonate is the well-known "marble" test, in which the water is placed in contact with calcium carbonate, and its increase or decrease in alkalinity noted. Using this test as a basis, McLaughlin[2] has developed a method of determining the quantities of chemicals necessary to saturate a given water with calcium carbonate. McLaughlin's method consists of adding to the water progressively increasing dosages of the chemical to be used, performing the "marble" test on each treated sample, and determining, by plotting, the dosage at which the water is exactly neutral to calcium carbonate.

More recently Langelier[3] has shown how the calcium carbonate saturation equilibrium may be calculated directly from the composition of the water, without resorting to the marble test. It is the purpose of this paper to show how Langelier's equation can be used in place of the marble test for computing the quantities of chemicals necessary to produce saturation in any given water. There are, in the writer's opinion, two reasons for preferring this method. One is that it eliminates a considerable portion of the laboratory work involved in the method of McLaughlin. The other is that the marble test is a somewhat unreliable determination except in the hands of a skillful and experienced analyst. The principal source of error seems to lie in the unavoidable exposure of the samples to laboratory air which

*Assistant Professor of Sanitary Chemistry, Harvard Graduate School of Engineering, Cambridge, Mass.

is heavily laden with carbon dioxide. Experience, particularly with Cambridge water, has also indicated that true saturation is frequently not attained as quickly as is commonly believed. In some cases, several days of standing in contact with calcium carbonate has failed to produce true equilibrium. The writer therefore feels that a method which avoids the use of the marble test is worthy of consideration.

Simplification of Langelier's Equation

The proposed method bases itself on the equation of Langelier (Reference 3, p. 1504), which gives the relationship between the pH, alkalinity and calcium content of any water which is saturated with calcium carbonate. The complete equation as given by Langelier expresses all concentrations in mols per liter. However, for the pH range usually encountered in water works practice the equation may be simplified and converted so that concentrations are in p.p.m. When this is done, the equation takes the form:

pH_s = K—logarithm of p.p.m. calcium as Ca—logarithm of p.p.m. alkalinity as $CaCO_3$.

pH_s, or the pH of saturation, is the pH at which a water containing the given number of p.p.m. of calcium and of alkalinity is in equilibrium with calcium carbonate. K is a constant obtainable by conversion of the constants given by Langelier (Reference 3, p. 1508). Its value depends on the temperature of the water and upon the total quantity of salts dissolved in the water, which is closely related to the total dissolved solids in the water. Table 1 contains a summary of the values of K for different solids concentrations and temperatures. The equation is valid between the limits of pH_s=6.5 and pH_s=9.5. For pH values outside this range, the complete equation (Reference 3, p. 1504, equation 9) may be used.

Table 1—Values of the Constant K.

Dissolved Solids p.p.m	Temperature of Water, °C.								
	0	10	20	25	50	60	70	80	90
0	11.50	11.39	11.29	11.24	11.03	10.95	10.88	10.81	10.74
20	11.59	11.48	11.38	11.33	11.12	11.04	10.97	10.90	10.83
40	11.63	11.52	11.42	11.37	11.16	11.08	11.01	10.94	10.87
80	11.67	11.56	11.46	11.41	11.20	11.12	11.05	10.98	10.91
120	11.71	11.60	11.50	11.45	11.24	11.16	11.09	11.02	10.95
200	11.76	11.65	11.55	11.50	11.29	11.21	11.14	11.07	11.00
280	11.81	11.70	11.60	11.55	11.35	11.26	11.19	11.12	11.05
400	11.86	11.75	11.65	11.60	11.40	11.31	11.24	11.17	11.10
520	12.91	11.80	11.70	11.65	11.45	11.36	11.29	11.22	11.15
680	12.96	11.85	11.75	11.70	11.50	11.41	11.34	11.27	11.20
800	12.98	11.88	11.78	11.72	11.52	11.43	11.36	11.29	11.22

Method of Calculating Chemical Dosages Required to Prevent Corrosion

The proposed method of calculating the quantities of chemicals required for the corrective treatment of any water can best be described by citing as an example an experiment performed on Cambridge raw water, to determine the amount of lime that would be required for such treatment. The sample of water tested had the following characteristics:

Temperature	20°C.
Dissolved Solids	70 p.p.m.
Alkalinity	20 p.p.m.
Carbon Dioxide	6.0 p.p.m.
Calcium	12 p.p.m.
pH	6.6

Noting that each part per million of hydrated lime added to the water will increase the calcium content by 0.54 p.p.m. as Ca, and the alkalinity by 1.35 p.p.m. as $CaCO_3$, we may calculate from the simplified Langelier equation the pH_s of saturation for any assumed dosage of lime. The appropriate values of K are 11.45 for the raw water, and 11.46, 11.47 and 11.48 respectively for the water dosed with 10, 20 and 30 p.p.m. of lime. These differences may be disregarded and the same value of K used for all computations. The results are shown in Table 2.

Table 2—pH_s of Saturation of Cambridge Raw Water.

Assumed Lime Dosage p.p.m. $Ca(OH)_2$	Ca	log Ca	Alk.	log Alk.	pH_s
0	12	1.08	20.0	1.30	9.07
10	17.4	1.24	33.5	1.53	8.68
20	22.8	1.36	47.0	1.67	8.42
30	28.2	1.45	60.5	1.78	8.22

A few minutes' computation will give any desired number of values. The values of pH_s so obtained are plotted against the lime dosage as shown in the accompanying diagram.

The next step is to add to samples of the water measured quantities of lime, and to determine the pH of the dosed samples. The results obtained on the sample in question are shown in Table 3.

The pH values so determined are plotted on the same diagram as the values of the saturation pH_s, as shown in the accompanying diagram. The point at which the two curves cross yields by inspection the required dosage of lime, and the pH of the corrected water. For the sample in question, the pH of the corrected water would be 8.6 and the lime dosage required would be 12 p.p.m. or 100 lb. per

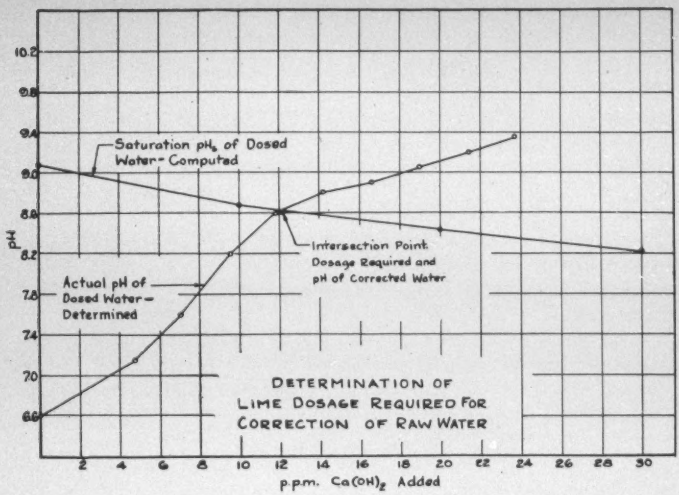

Saturation pH_s of Dosed Water - Computed
Intersection Point Dosage Required and pH of Corrected Water
Actual pH of Dosed Water - Determined
DETERMINATION OF LIME DOSAGE REQUIRED FOR CORRECTION OF RAW WATER
pH
p.p.m. $Ca(OH)_2$ Added

TABLE 3—EFFECT OF ADDED LIME ON pH OF CAMBRIDGE RAW WATER.

Lime Added p.p.m $Ca(OH)_2$	pH	Lime Added p.p.m $Ca(OH)_2$	pH
0	6.60	16.6	8.90
4.75	7.15	19.0	9.05
7.10	7.60	21.4	9.20
9.50	8.20	23.7	9.35
11.9	8.60	35.5	10.20
14.2	8.80		

m.g. The result was checked by making a marble test on the water, which also gave an equilibrium pH of 8.6. Eight hours of steady shaking were required to establish this equilibrium, a fact which illustrates the chief disadvantage of the marble test.

As a matter of record, the alkalinity of the Cambridge raw water is reduced to about 7 p.p.m. during coagulation, and the resulting water is corrected after filtration. Under these circumstances similar computations show a required lime dosage of 110 lb. per m.g. and a final pH of 8.8, which is in agreement with present plant practice.

The same diagram may also be used to calculate the dosage required for any other desired degree of treatment. For example, if the water is to be adjusted to a Langelier Saturation Index of —0.2,

a line is drawn parallel to the pH_s line but 0.2 units below it. The intersection of this line with the pH line gives the required dosage.

Chemicals Used in Corrective Treatment

The chemicals which have been used in that type of corrective treatment which aims at the production of a water saturated with calcium carbonate are unslaked lime, hydrated lime, soda ash, caustic soda, and limestone, the latter in the form of beds. The proposed method of calculation of the required dosage applies to all of these chemicals, the only requisite being a knowledge of the amount of calcium and of alkalinity added per p.p.m. of added chemical. This information is given in Table 4.

Table 4—Calcium and Alkalinity Added by Corrective Chemicals.

Chemical	Each p.p.m. of chemical added to the water adds: p.p.m Calcium as Ca	p.p.m. Alk. as $CaCO_3$
Lime, CaO	0.72	1.78
Hydrated Lime, $Ca(OH)_2$	0.54	1.35
Limestone, $CaCO_3$	0.40*	1.00*
Soda Ash, Na_2CO_3	——	0.94
Caustic Soda, NaOH	——	1.25

*For each p.p.m. $CaCO_3$ dissolved from the limestone bed.

In calculating pH_s, these factors are multiplied by the dosages assumed and the resulting values are added to the initial calcium and alkalinity content of the water. They are based on 100% pure chemicals; therefore, the required chemical dosage, as found, must be corrected for the impurities contained in the chemicals to be used. Commercial soda ash averages about 98% pure, lime about 85%, hydrated lime about 90%, and caustic soda about 76%. Thus, if the dosage of lime required is found to be 10 p.p.m. of pure $Ca(OH)_2$, the actual dosage of the impure chemical to be delivered by the chemical feeder will be $10 \times \frac{100}{90}$ or 11.1 p.p.m.

It will be noted that the addition of lime compounds has a double effect in lowering the value of pH_s in that it increases both the calcium and the alkalinity of the water. This explains why lime compounds are most satisfactory for the correction of soft New England waters, whereas soda ash may be entirely suitable as a corrective for harder waters in which further increase of calcium is unnecessary.

There is, however, an important point which should be brought out in connection with the use of lime or hydrated lime as a cor-

rective agent. Since hydroxide alkalinity plays no useful part in saturating a water with respect to calcium carbonate, there must be present in the water a sufficient amount of carbon dioxide and bicarbonate alkalinity to convert the added lime to calcium carbonate. Hence, for hydrated lime, $Ca(OH)_2$, the dosage in p.p.m. of pure chemical should not exceed the sum of 1.68 times the p.p.m. CO_2 and 0.74 times the bicarbonate alkalinity as $CaCO_3$, and for unslaked lime, CaO, the dosage should not exceed 1.27 times p.p.m. CO_2 plus 0.56 times bicarbonate alkalinity. Any lime added in excess of these quantities exerts only the single effect of its calcium content. Caustic soda is of limited value as a corrective agent for the same reason, and is at a greater disadvantage than lime, since it adds no calcium to the water. These facts explain why some soft New England waters which are also low in carbon dioxide and alkalinity cannot be successfully corrected for their corrosiveness by the use of lime alone. Computations similar to those illustrated in this paper will show that such waters may be successfully treated to saturation with respect to calcium carbonate by a suitable combination of *lime and soda ash*.

Advantages and Disadvantages of Proposed Method

The advantages of the proposed method of determining corrective chemical dosages over the usual method of running marble tests on several dosed samples of water lie largely in the reduction in the amount of laboratory work required. For the series of marble tests there is substituted a series of simple calculations based on the Langelier equation. This equation has been thoroughly checked by Langelier (Reference 3) and De Martini,[4] so that there should be no question as to its validity. Furthermore, the attainment of true equilibrium in the marble test requires shaking for several hours, sometimes even days. The five and ten minute contact periods frequently quoted in the literature are entirely inadequate. The pH determinations on the dosed samples of water are quickly and easily made, and a complete determination of the dosage of corrective chemicals required may be made in a half-hour.

One disadvantage of the method is that it requires a knowledge of the calcium content of the water, which is not ordinarily determined in routine analyses. However, the volumetric determination of calcium (Standard Methods of Water Analysis, 8th Ed., p. 79) is a relatively simple procedure, especially since a filter paper is an entirely satisfactory substitute for the Platinum Gooch crucible required, for no readily apparent reason, in the procedure. The new

procedure of Brazeale and Greene[5] appears to be the simplest and most rapid method of determining calcium yet developed.

Furthermore, the calcium determination need not necessarily be repeated every time the chemical dosage is checked, since it often remains practically constant over long periods of time, and even in the case of flashy waters is usually a relatively fixed proportion of the total hardness. The calcium content therefore may only need to be determined at intervals, and may be estimated from the hardness at other times. As an example, the writer has checked the calcium content of Cambridge raw water over an extended period, and has found a variation of only one p.p.m. The dissolved solid content of the water need only be known approximately, since the corrections involved are small in magnitude.

In conclusion, it is hoped that the proposed method of calculating chemical dosages will serve as a useful tool for practical water works men.

References

1. Gilcreas, This Journal, **51**, 380 (1937).
2. McLaughlin, Water Works and Sewerage, **83**, 81 (1936).
3. Langelier, Jour. Am. Water Works Assn., **28**, 1500 (1936).
4. De Martini, Jour. Am. Water Works Assn., **30**, 85 (1938).
5. Brazeale and Greene, Jour. Am. Water Works Assn., **30**, 1040 (1938).

MAINTAINING A DISTRIBUTION SYSTEM IN NORTHERN NEW ENGLAND

BY JAMES A. SWEENEY*

[*Read May 12, 1938.*]

To carry out efficiently the operation and maintenance of a water system in any community, the first requirement is proper supervision. Those responsible should be men of exceptional ability in this profession and regarded by the public as men who know "what it is all about"; the office force whether they be men or women, must know something of what makes water bills high and the causes of the most common complaints; the engineering force must know pretty well what to do after they are given a preliminary plan of what is wanted; and so on down through to the common laborer. I believe that if the proper persons are kept in the positions for which they are best suited in a Department and "politics" are kept out, one can be assured that things will go along very well. I also believe that those in a responsible position within the department should be well paid, because they will be more satisfied and will do better work than if they are underpaid.

Distribution System. We all agree that the design of a distribution system should meet the following primary requirements. First, to supply adequate quantities of clear, wholesome water to each tap with the least inconvenience to the consumer through interruption of service. Second, to furnish in case of a fire, or series of fires, large volumes of water within a small area that might be located in any part of the system. In the first case of supplying water for domestic and commercial purposes, experience has told us that the average system can take care of this consumption very well. The second for supplying water for fire purposes must be given a great deal of thought and planning to meet the quantities required by fire-insurance companies and boards.

The water-supply system of Manchester, N. H., is now 67 years old and serves an area of approximately 40 sq. miles and more than 80,000 persons, including parts of five adjoining towns. This area is served by three distribution reservoirs through 192 miles of mains. The piping is so connected and controlled by valves that either pressure can be turned into either system by operating gate valves,

*Assistant Superintendent, Manchester Water Department, Manchester, N. H.

or through pressure-regulating valves which operate automatically. We have two high-pressure and one low-pressure reservoirs with a total capacity of 40 m. g., equal to eight days' supply for our consumers at the present time.

Distributing Reservoirs. Reservoirs must be protected from the general public by fencing. Our experience has been that wooden fences require a great deal of maintenance and are not to be compared with wire fences. Our three reservoirs are surrounded by wire fences of Cyclone design, 8 ft. high, with a bar or arm set at the top of each post and extending outside at a 45-deg. angle through which is strung barbed wire, and this has proved satisfactory. Reservoirs, such as ours, need inspection and cleaning. In order to do this, they must be drained, and when emptied we use a centrifugal suction pump connected to a hydrant located just outside the inlet chamber of the reservoir. We then wash down the sides and bottom, the sludge and water being taken away by the drain located in a low corner of the reservoir. Screens located at inlet and outlets are changed twice each year, removed and cleaned with a broom.

Dead Ends. In any system there are many dead ends which cannot be eliminated without too much expense, and so they must be flushed periodically. We flush in the spring and fall and oftener on complaint of the consumers.

Frozen Mains. During the cold winter of 1933-1934 6- and 8-in. mains were frozen at a depth of 5-ft. cover in gravel. While we have been able to thaw mains up to 6 in. in size, we have not been able to get a current through pipes having a non-conductor joint, such as Leadite, or Hydro-tite. It is claimed that after some years these joints will carry sufficient current to thaw the line. We were able to confine our frozen mains to five different places by bleeding. All but two of these were on dead ends, and all were lowered the following spring. All pipe trenches since 1933 are dug 6 ft. deep.

Services. The maintenance of more than 11,000 services is no small job. The replacement of old services is due to pipe tuberculation and reduction of flow. For the last few years we have been laying approximately 75 new and replacing 400 old services. Service leaks are 75% of our trouble caused by lead goose necks leaking or splitting. Copper tubing has been used since 1927, and in only two cases have we had leaks. These were at the joints and were caused by improper construction. We cut out a section of one of the first copper services laid and found it as good as when first installed. Lead-lined pipe has given some trouble due to the lining being eaten through and corrosion starting at the iron pipe. Some of our cement-lined

service-pipes have shown deterioration, softening the cement so that one can scrape it off with his finger nail. The use of lead or lead-lined pipes has been prohibited in New Hampshire by the State Board of Health. Frozen services are thawed by an Engessor Thawing Machine capable of generating 400 amp. During thawing operations, services are disconnected in the cellar and the meter and ground-wire removed from the line. This ground connection is later replaced by a journeyman electrician.

Water Mains. In the opinion of the writer, mains, if well laid and of the proper class of pipe for the pressure they have to work under, will give little trouble. Our experience has been that most of the trouble lies not in the quality of material used, but in the way in which it is laid. Pipe should not be laid too close to stone or ledge. This was proved to us during the cold winter of 1933-1934 when we had three circumferential cracks in 6-, 8-, and 12-in. mains caused by the action of frost on the soil. These were repaired by using split repair-sleeves. Pipes laid under railroad tracks are subject to vibration and are laid with a minimum cover of 6 ft. I recall one 8-in. joint under a crossing which gave us considerable trouble. This joint leaked regularly once a year, usually in the spring. The last time it was repaired, a bell clamp-sleeve was used, and since then we have had no trouble.

River Crossings. Pipes crossing under rivers or brooks or on bridges, unless properly laid, will cause no end of trouble for the department. For example, in the summer of 1920, a covered, wooden traffic bridge carrying a 12-in. high pressure line to West Manchester collapsed, due to old age. It meant getting another line across as quickly as possible. Flanged pipe 20 in. in diameter was used and laid on the bottom of the Merrimack River, with no trench work being done. We had breaks and leaks on this, until we protected it by concreting on the upstream and downstream side of the pipe. If before this line was laid, a grade had been established and a coffer dam built with the grade of the top of the pipe below the river bottom so that any action from the river would be over the pipe and not against it, I believe no trouble would have developed.

Gate Valves. The importance of gate valves in the proper locations and kept in condition for easy operation has been brought home to every water works man at some time. Gate valves should be so placed that in case of a break, or when necessary changes in the system are being made, interruption of service will affect only a small area and a minimum number of families. In connection with the operation of some of our large valves some years ago, we found that

the short pinion shafts were actually frozen in the bearing and could not be operated until taken out and cleaned. This occurred on some of the older valves, where no grease cup was inserted. We remedied this by tapping and drilling an Alemite grease-cup through the bearing and greasing it with a pressure gun. Now one man can easily operate any one of our 20- or 24-in. gates. All valves larger than 12 in. are housed in pits which allow of easy access to make any necessary minor repairs or replacements. In 1934, we purchased a Homelite Generator set and Toledo Gate-operating Device, and we use this altogether on valves 12 in. and larger in size. We find this a good investment for it allows us to go over our large valves much oftener and in a great deal less time. The generator is also used for night lighting and will generate power for 1500 watts of lamps.

I believe where 6- and 8-in. pipes connect and cross at an intersection, the expense involved of setting three gates is justified. Where larger sized pipe is used, the spacing may be longer.

Hydrants. We have ten different makes of hydrants in the system, and the compression type predominate. All have two 2½-in. hose outlets and one 4½-in. steamer outlet. These are inspected regularly, and the frequency of winter tests depends on the low temperature. Hydrants used by the Fire Department are inspected immediately after use. While the compression-type hydrant has the advantage of causing less water hammer, and in case of breakage by automobile will not flood, one disadvantage is that it may be broken; and unless it is actually pressure tested, one does not know whether or not it is in working condition. We make a complete fall and spring inspection of all hydrants by this pressure test. Hydrants set in very wet places are subject to ground-water backing up through the drip and standing in the barrel high enough to freeze. In such instances, the drip is plugged, and the hydrant is pumped out after being used. Many of our hydrants have a flange near the ground line which had iron bolts that corroded so badly in a few cases that the hydrant top actually blew off while in use, so we resorted to the use of bronze bolts, and during the last year the job of replacing all iron bolts with bronze bolts was completed.

In our northern climate, mains and services cannot be laid as shallow as in places where the temperature rarely drops below freezing. Pipes over rivers or in other exposed places, unless the velocity of the water is high enough to prevent freezing, have to be bled throughout the winter.

Hydrants must have frequent inspection in cold weather and looked over immediately after use. If the ground is frozen deep,

the drain may not work as quickly as in mild weather, and there have been instances of the hose- or steamer-cap being put on too quickly after using the hydrant and creating a vacuum and not allowing the water to drain out. In some soils, gravel has to be placed around the barrel of the hydrant to the ground level to prevent the casing from moving upwards due to frost action. Valve boxes have also risen as much as 4 in. above ground level.

Curb Boxes. Curb boxes of which we have approximately 11,000 are a great source of trouble. In the spring, we go over our entire system and drive them down with a pick handle to get them down to grade. In this connection we recently lost a suit in court where a woman tripped and fell over a raised box breaking her wrist. The court awarded her $876.00, but counsel for the city have appealed this verdict to the State Supreme Court on exceptions.

Meters. Care must be taken that meters are set for protection against frost.

Mechanical Equipment. As in other modern business, the trend has been to speed up, and so mechanical equipment in good condition is needed. Portable air-compressors with jackhammers and paving-breakers are a big help, especially when the ground is frozen, also gasoline-driven pumps to drain cellars or excavations.

Our Department has the following equipment:

3 Portable air compressors
3 Gasoline-driven pumps
1 Homelite generator set with lights
1 Toledo gate operating device
1 Engessor 400-amp. generator used for thawing
2 Portable steam boilers
1 Pipe locator
1 Leak finder

and other small equipment such as Sonophones, magnetic dipping needles, Meter Master and portable pressure recorder. We have a new up-to-date garage where most of the above equipment is stored, also trucks and cars. An air-operated lift and greasing by air pressure has kept down the maintenance cost on mobile equipment. This garage is automatically steam heated by oil. It has been our experience that equipment when taken to a job at 2 A. M. with the temperature at 20° F. below zero will function much better than if stored in an unheated garage or shed.

Records. Clear concise records must be kept up to date by the engineer and must be available for use of foremen. Plans of our entire piping system, showing measurements to pipes and gates and

bound in loose leaf books, are kept in each of the construction and service trucks for use for general work or emergency. These are very important as we normally have several months of the year when the ground is covered with snow.

Office records in the form of maps are kept, showing location and size of all mains and valves. Duplicate sets of gate, hydrant and service cards are kept, giving location, kind and dates of operation and maintenance work done on each.

BRISTOL'S NEW FILTRATION PLANT

BY JAMES A. NEWLANDS*

[*Read April 14, 1938.*]

The city of Bristol, Connecticut, has a population of about 33,000 with approximately 30,000 served by the Water Department. The average daily water consumption, completely metered, is about 2,250,000 gallons of which 45% is used for domestic purposes and 55% for industrial and municipal requirements.

Source of Supply. The supply is obtained from five upland reservoirs located on Poland River or its tributaries at points 1½ to 8 miles from the city.

First developed by a private water company in 1885, the plant was purchased by the city in 1914 and has since been operated by a Commission of three citizens. As long-time service on municipal commissions is the exception rather than the rule, it is of interest to note that the present chairman, Mr. Charles L. Wooding, was one of the original members. The secretary, Mr. William E. Tracy, has been a member of the Commission for eighteen years, and Mr. Townsend G. Treadway has served for eight years. Mr. G. E.

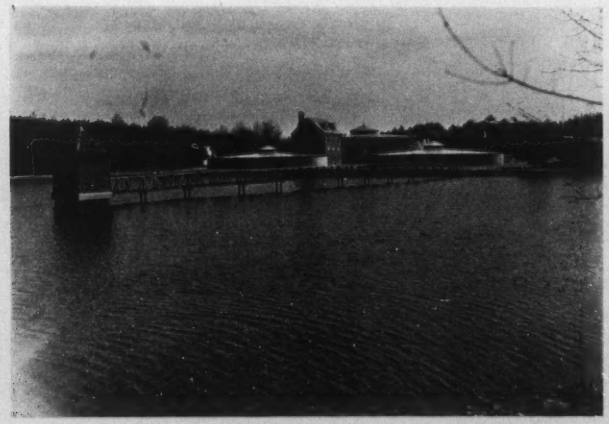


FIG. 1—GENERAL VIEW OF BRISTOL WATER PURIFICATION PLANT.

*Consulting Engineer, Hartford, Conn.

Lourie has been in continuous charge of plant operations for the past seventeen years.

The Commission has continued a policy, started by the original company, of purchasing properties adjoining the reservoirs and their tributary streams in order to eliminate, so far as practicable, direct contamination of the water. Numerous houses and their accompanying barns and outbuildings have been purchased and removed. Areas near important highways have been protected by fences. The Department now owns 3,525 acres of land or approximately 54% of the total drainage area of 10.2 sq. miles. In addition to this method of protection, the water has been chlorinated since 1923.

Although these measures have been effective in safeguarding the sanitary quality of the water, the supply, like many other surface waters, has been unsatisfactory, at times, because of objectionable tastes, odors, and discoloration. Continuous copper-sulphate treatment of the water entering the distributing reservoir during the summer months has been used with fairly satisfactory results in the control of tastes and odors, but consumer objections to discoloration have persisted.

Filtration Works. During the early part of 1936, while investigating methods for satisfying objections to the physical appearance of the water, the attention of the Commission was directed to the use of rapid sand filters, several of which were then under construction for other Connecticut cities. Consideration was given to both the standard type of concrete plant and the Morse type constructed of steel.

In determining the merits of the two types of construction, it was recognized that while the modern gravity rapid sand filter plant has ordinarily been constructed of concrete, the successful use of iron and steel pressure filters at Atlanta, Georgia; Davenport, Iowa; Greenwich, Connecticut, and other places over periods of forty to fifty years has clearly demonstrated that these materials, from the standpoint of long life, are not without merit for water purification projects.

Corrosion of iron and steel surfaces in contact with water has been an objectionable feature in the past, but in recent years this problem has been materially lessened by improvements in the quality of protective coatings.

The production of stronger and better steel structures has also been made possible by the remarkable advances in the development of welding technique. Both gas and electric welding processes are now used in the fabrication of many complicated steel structures

FIG. 2—INTERIOR OF BRISTOL WATER PURIFICATION PLANT.

ranging from battle cruisers and ordnance for exacting service requirements to welded pipe lines, high-pressure steam boilers and other units built for continuous performance and long life. National engineering bodies have coöperated with federal authorities and insurance interests to promote the development of proper welding practice, adequate inspection methods and suitable material for nearly every type of structural unit.

As previously indicated, steel pressure filters have been used in the purification of water over a period of about fifty years, but it remained for the late Robert B. Morse to direct attention to the practicability of fabricating concentric circular steel tanks for gravity-type filters when he built a plant for the Washington Suburban Sanitary District at Burnt Mills, Maryland, about four years ago. A second unit for the district has since been constructed.

Following two visits to the Burnt Mills plants and a new filter plant of concrete construction, the Commission accepted the writer's report advising the installation of a plant, with a capacity of 5 m.g.d., similar to those at Burnt Mills, but with a considerable number of changes in design, some of which were necessitated by differences in local conditions.

A contour map of the site was prepared by City Engineer, Carleton E. Buell of Bristol, and the contract was let to The Chicago Bridge and Iron Company on December 30, 1936. Grading for the

foundations was begun on March 26, 1937, and the underground piping and reinforced concrete mats for the filter unit and clear-water tanks were completed on June 1. Erection of the superstructures was started on May 18. It is proposed now to deliver water to the city about the end of April, 1938.

It is of interest to note that as a result of very thorough tests of each steel compartment no leaks were found in the welded sections. A few small leaks at pipe flanges were stopped by tightening up the flange bolts.

While the shape of the plant differs from the usual rectangular tanks used in concrete construction the operating units are the same. The filters are equipped with the usual rate controllers, loss of head and rate of flow gauges and all valves in daily operation are hydraulically operated from tables on the central operating-floor.

In order to increase the head in the city by about ten feet, the raw water is elevated from the reservoir level to the filters by two

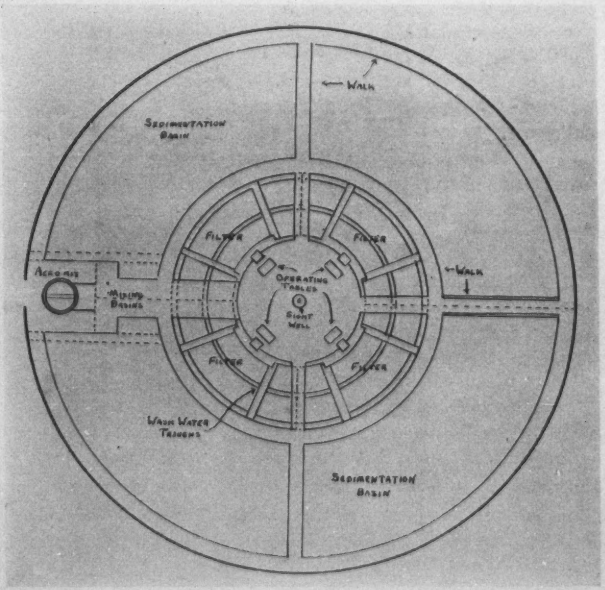


Fig. 3—Plan of Coagulation Basin and Filters, Bristol, Conn.

1¼-m.g.d. and two 2½-m.g.d. pumps used as required to supply one or more of the four filter units each of which has a capacity of 1¼-m.g.d. at a filtering rate of 2 g.p.m. per sq. ft. of sand surface. The pumps are motor driven by purchased power, but it is proposed to install later Diesel engines and generators as an additional source of power.

Dry-feed chemical machines supply coagulants to the raw-water line in the pump house. The treated water flows to two Aer-O-Mix units and two mixing tanks which have a detention period of 15 min. at maximum rating. The water then discharges over weirs at each side of the mixing tanks to the two coagulating basins which have a detention period of 4 hours. At the outlet ends of the semi-circular coagulating basins the water passes over weirs to down-take pipes into the pipe vault then to the filter units as required. As the aerating, mixing, and coagulating basins are in duplicate, any unit can be put out of commission when necessary without interfering with the general operation of the plant.

The four filter units, located between the central operating floor and the semi-circular coagulating basins, each have a sand surface area of 434 sq. ft. Eighteen inches of graded gravel and twenty-four inches of Cape May sand, having an effective size of 0.47 mm. and a uniformity coefficient of 1.70 are supported on a perforated steel filter bottom.

The filter effluent discharges to the sight well in the center of the operating floor. The filtered water then discharges into a 20-in.

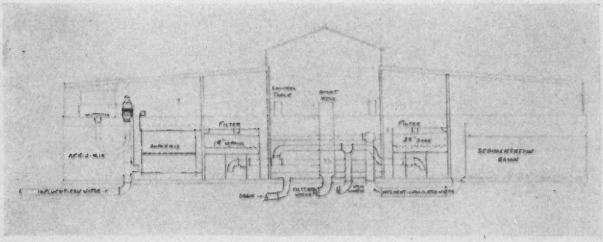


FIG. 4—CROSS SECTION OF COAGULATION BASIN AND FILTERS, BRISTOL, CONN.

line through the pump house where lime is added to eliminate corrosive characteristics before the water passes to two clear-water tanks, each of which has a capacity of 400,000 gal.

Beyond the junction of the clear-well outlets, the water passes through a Venturi tube and then to the distribution system. The

Venturi indicator-recorder, located in the pump room, enables the operator to regulate the rate of filtration in accordance with the city demand, and another recording guage shows the water level in the clear-water tanks.

The filter plant structure is 118 ft. in diameter and the interior surfaces above the operating-floor level are covered with 1½-in. cork. The same covering is used in the pump and chemical house. The interior wall of the sight well and the interior of the aeration chamber are lined with white tile. The sight well is equipped with an underwater light, and the bottom section around the outlet pipe is lined with alternate black and white tile.

All steel surfaces below the water level have been cleaned with mechanically operated wire brushes to remove rust, and the surfaces have been painted with four coats of a bakelite paint. The outside metal surfaces of the filter plant and the clear-water tanks have been wire-brushed and covered with three coats of gray enamel paint.

The filtered-water storage now available with the two clear wells at the filter plant, a steel standpipe and a high-service reservoir in the city totals 1,572,000 gal. and this with the filtering capacity of the plant will meet all fire-service requirements.

There are two wash-water tanks, each having a capacity of 25,000 gal. with a head of 27 ft. above the wash-water trough overflow-line. Filtered water is pumped to the wash-water tanks by two centrifugal pumps located in the pipe vault and automatically controlled by the water elevation in the tanks.

The pump and chemical house, three stories high, has a storage room for chemicals on the top floor. Four dry-feed chemical machines are on the second floor, and chlorine equipment, now located in another building, is to be moved to this room. The laboratory is also on the second floor. The pump room on the first floor has space available for the installation of Diesel engines and electric generators. Heating equipment, pumps and tanks for high-pressure service-water are located in the basement.

Operations to date have shown that water with a color below 5 p.p.m. and practically no turbidity can be produced with not more than ¾ grain of alum per gallon of water, and a pH of 8.3 to 8.5 can be maintained in the filtered water with about 1 grain of lime per gallon.

The contract price for the filter plant, pump and chemical house, and two clear-water tanks was $152,000. The wash water settling basin, pipe lines between the plant and the distributing system, engineering and so forth, will bring the total cost to about $170,000.

Acknowledgments. I wish to acknowledge at this time, my indebtedness to the representatives of the Chicago Bridge and Iron Company, general contractors. I am especially indebted to Messrs. Harry B. Shaw, A. A. Kenney, E. F. Humm, and L. C. Stiles, all of whom have contributed to the solution of problems which have arisen, and I am sure that the water commissioners and Mr. Lourie will join me in this expression of appreciation.

THREAD GAGE DESIGN AND THREADING PROBLEMS

BY OSCAR E. KOEHLER*

[*Read May 20, 1937.*]

Many engineers and maintenance superintendents are inclined to believe that the gaging of screw threads is not a vital part of their particular field of endeavor. However, a passing knowledge of its value and proper use may on various occasions save much time and money. When we consider the many mechanical devices dealt with during the course of a year, most of which are manufactured in mass production, we realize that somewhere along the line thread gages are used, or should have been used.

In a recent issue of the "Tool Engineer", a new definition of "gage" reads, "A gage is a device to improve quality, facilitate production, and reduce cost." Therefore, when considering the purchase of new equipment and maintenance requirements it should be of interest to know whether or not the manufacturer uses gages on the product and especially when dealing with screw threads, the class of fits used. With this in mind it is hoped that the following brief description accompanying various illustrations will be of some value for future reference.

Screw Thread Notation. Correct terms to use in referring to

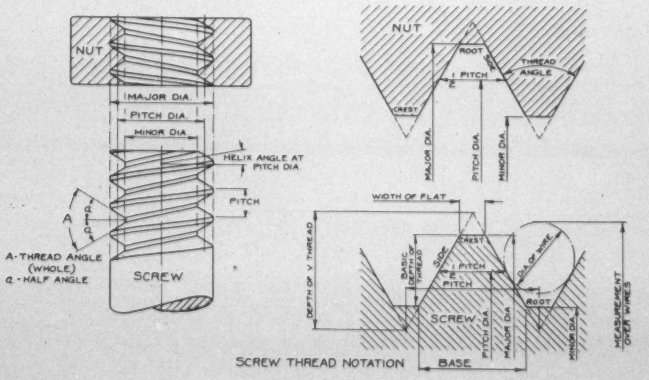


FIG. 1—SCREW THREAD NOTATION.

*Chief Engineer, Greenfield Tap and Die Corporation, Greenfield, Mass.

screw threads and a recognized code of marking used on gages, taps, dies, and screw threads are shown in Figure 1.

Symbols commonly used in American practice are:

N.C.—American National Coarse Thread Series
N.F.—American National Fine Thread Series
N.S.—American National Special Thread Series
N.H.—American National Hose Coupling Threads
N.P.T.—American National Taper Pipe Threads
N.P.S.—American National Straight Pipe Threads
GREASE—a standardized undersize straight pipe thread
STEAM—a straight pipe thread used on coupling taps
CONDUIT—an oversize straight pipe thread used on coupling taps
V—indicating a 60-deg. V thread usually with both the crest and root flatted several thousandths from the theoretical to the user's specifications
ACME—a standardized 29 deg. thread
S.B.—manufacturers stove bolt standard thread.

Such markings as U.S.S., U.S.F., S.A.E., and A.S.M.E. are now obsolete.

Gages, taps and dies having multiple threads are marked with diameter, number of threads to the inch, form of thread and lead designated in fractions; also double, triple or quadruple. For example: A 1-in.-16 double-thread special tap with National form of thread will be marked as follows: 1-in.-16 N.S.; ⅛-in. Lead Double.

The same tap with Acme thread will be marked as follows: 1-in.-16 Acme; ⅛-in. Lead Double.

There are two measurements of a screw thread of vital importance, the pitch or lead and the pitch diameter defined as follows:

Pitch—The distance from a point on a screw thread to a corresponding point on the next thread measured parallel to the axis. The pitch in inches $= \frac{1}{\text{Number of threads per inch}}$

Lead—The distance a screw thread advances axially in one turn. On a single-thread screw the lead and pitch are identical; on a double-thread screw the lead is twice the pitch; on a triple-thread screw the lead is three times the pitch, etc.

Pitch Diameter—On a straight screw thread, the diameter of an imaginary cylinder, the surface of which would pass through the threads at such points as to make equal the width of the threads and the width of the spaces cut by the surface of the cylinder. On a taper screw thread, the diameter, at a given distance from a reference plane perpendicular to the axis of an imaginary cone, the surface of which would pass through the threads at such points as to make equal the width of the threads and the width of the spaces cut by the surface of the cone.

The most common means of measuring the pitch diameter of

screw threads is by the so-called "three-wire method", in which small hardened steel cylinders or wires of correct size are placed in the thread groove, two on one side of the screw and one on the opposite side, over which a micrometer reading is taken from which increment deductions are made to ascertain the pitch diameter. The wires used should be round within 0.00002 in. and straight to 0.00002 in. over any quarter-inch interval. Further details may be found in the Report of the National Screw Thread Commission, published by the U. S. Department of Commerce (Bureau of Standards) and some tap and gage manufacturers' catalogs.

Tolerances Illustrated for Classes of 1-in.-8 N. C. These are the recognized classes of fit in general use (Fig. 2):

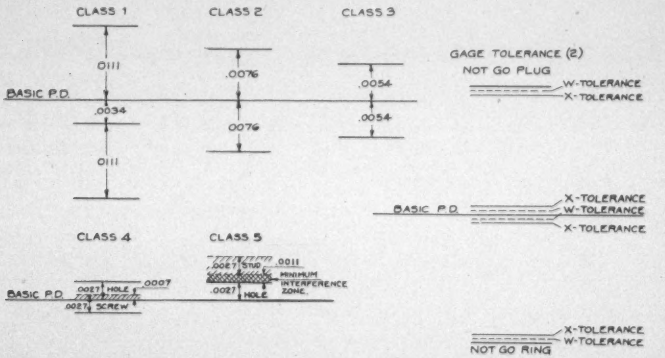


FIG. 2—CLASS TOLERANCES FOR 1-INCH-8 N.C. THREADS.

Class 1 (Loose fit) is for cheap classes of threaded work where a certain amount of shake is not objectionable. However, a Class 1 hole in the smaller sizes and fine pitches is a good job, and a great deal of threaded product is actually in this class.

Class 2 (Free fit) is standard for commercial product such as bolts, nuts and screws.

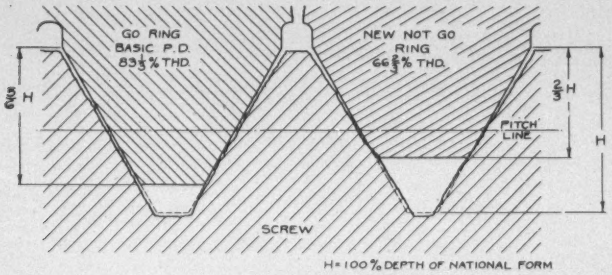
Class 3 (Medium fit) is the next popular class of fit, including the better grade of interchangeable screw thread work, and has about 70% of the tolerance allowed for Class 2.

Class 4 (Close fit) includes screw-thread work requiring a snug fit. The maximum screw is slightly larger than basic and the total tolerance is 50% of Class 3.

Class 5 (Wrench Stud fit) carries the same tolerances as Class 4 but so located that the minimum screw is larger than the maximum hole. At all times a metal to metal interference prevails, creating a wrench fit for studs.

The application of the gage tolerances is also shown to be within the product tolerances and in most cases favors the wear in the working gages that are most used, i.e., the Go Plug is made with the tolerance applied plus and the Ring is set to a check which has the tolerance applied minus. The Class "W" gage tolerance which is about one-half of Class "X" gage tolerance is used on gages for Class 4 and 5 where the production tolerance is small.

The Go Ring Thread Gage (Fig. 3) is truncated 1/6 H at the minor diameter or 83 1/3% (equivalent to a flat of ¼ P). This gives a maximum depth of engagement on the screw equivalent to the maximum engagement of any nut, as the tap drill size is 83 1/3% to 75% or less for all kinds of tapped holes.



1"-8 CLASS 2

FIG. 3—RELATION OF GO AND NOT GO RING THREAD GAGE TO SCREW THREAD.

The Not Go Ring Gage is truncated to 66 2/3% depth (equivalent to a ⅜ P flat). This checks the thickness of thread near the pitch line so that thin threads are not passed.

The Go Plug Gage is full form as all classes of screws may have full form. The maximum outside diameter is basic with a plus tolerance. The gage makers tolerance (Class "X") is applied plus from basic on pitch diameter.

The Not Go Plug Gage (Fig. 4) is truncated 1/6 H or less 83 1/3% of thread giving a flat of ¼ P with the object of not passing thin threads or wide angle threads.

The Standard or Basic Ring Gage was *formerly* made with full form of thread, i.e., with basic minor diameter and so it is standard practice to make dies and threading tools with basic form, i.e., with ⅛ P flat at crest of thread, it is evident that as soon as this crest in the dies began to wear and the corners rounded off the full form gages would bear only at the root of the thread, and then the dies

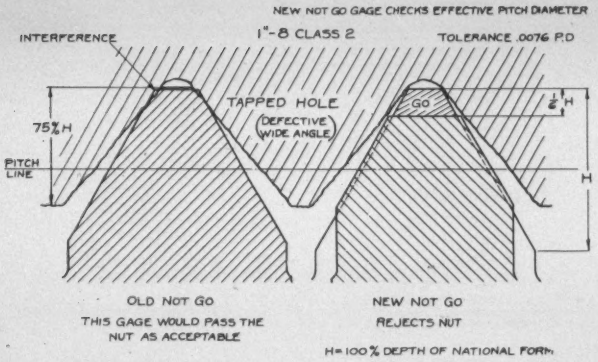


FIG. 4—RELATION OF NOT GO PLUG GAGE TO SCREW THREAD.

would be adjusted to cut a smaller pitch diameter than necessary in order to have the gage go on. This was one of the first reasons for enlarging the minor diameter of the Go Ring. See Figure 5.

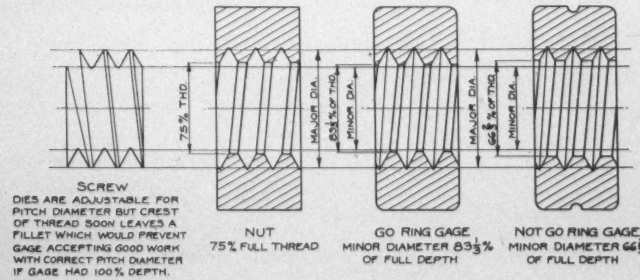

75% THD
MAJOR DIA.
83⅓% OF THD.
MINOR DIA.
MAJOR DIA.
66⅔% OF THD.
MINOR DIA.
SCREW
DIES ARE ADJUSTABLE FOR PITCH DIAMETER BUT CREST OF THREAD SOON LEAVES A FILLET WHICH WOULD PREVENT GAGE ACCEPTING GOOD WORK WITH CORRECT PITCH DIAMETER IF GAGE HAD 100% DEPTH.
NUT
75% FULL THREAD
GO RING GAGE
MINOR DIAMETER 83⅓%
OF FULL DEPTH
NOT GO RING GAGE
MINOR DIAMETER 66⅔%
OF FULL DEPTH

FIG. 5—AMERICAN NATIONAL FORM OF THREAD.

Taps are made with an outside larger than basic to a maximum amount of about 1/16 P. This is to provide for wear at the crest corners of the tap. It is the rounding of these corners and consequent interference at the crest of the Go Plug gages that makes holes appear smaller. If the crest of the tap is too sharp in proportion to the pitch the wear is also too rapid for maximum production. See Figure 6.

A frequent cause of loose assemblies in addition to those caused by crest wear is angle error. Sometimes the included angle is 60 deg.,

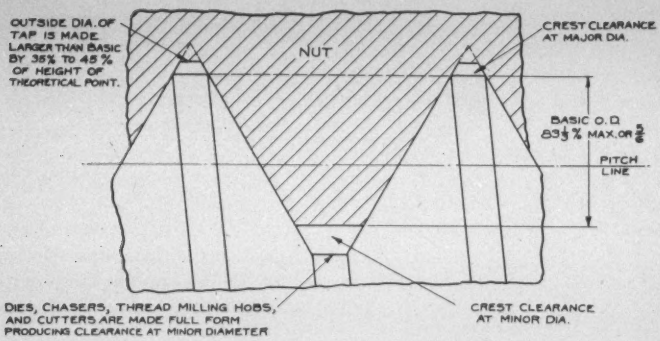

OUTSIDE DIA. OF TAP IS MADE LARGER THAN BASIC BY 38% TO 45% OF HEIGHT OF THEORETICAL POINT.
NUT
CREST CLEARANCE AT MAJOR DIA.
BASIC O.D. 83⅓% MAX. OR 5/6
PITCH LINE
DIES, CHASERS, THREAD MILLING HOBS, AND CUTTERS ARE MADE FULL FORM PRODUCING CLEARANCE AT MINOR DIAMETER
CREST CLEARANCE AT MINOR DIA.

FIG. 6—MAXIMUM METAL CONDITION OF IDEAL SCREW ASSEMBLY.

but it is not symmetrical with the axis. The parts are tight on the gages but when assembled are exceedingly loose. Truncated Not Go Gages prevent parts being passed that have excessive faults. See Figure 7.

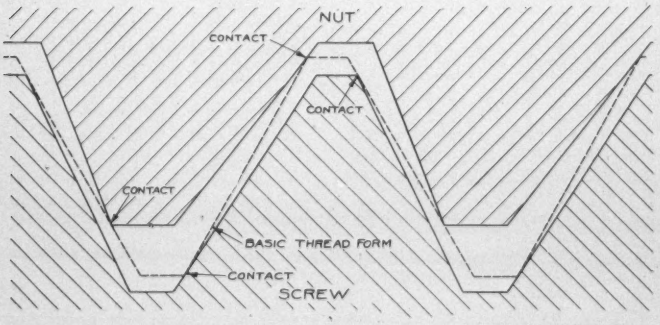


FIG. 7—LOOSENESS IN ASSEMBLY CAUSED BY ANGLE ERRORS.

Lead Error is another fault. This usually appears like a bell mouth or tapered part, because the gage is loose at starting but tightens up. The contact is being taken by the end threads when a point is reached where the lead error uses up the difference in pitch diameter. The Not Go Gage is also an effective control, but ground thread taps eliminate this fault economically. See Figure 8.

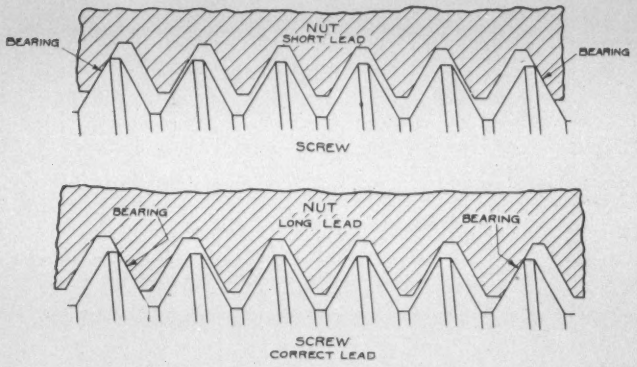


FIG. 8—LOSS OF BEARING CONTACT DUE TO LEAD ERROR.

Occasionally we have cases where parts that pass thread limit gages are tight on hand assembly jobs. This is usually due to lack of checking the outside diameter of the screw or the minor diameter of the hole. See Figure 9.

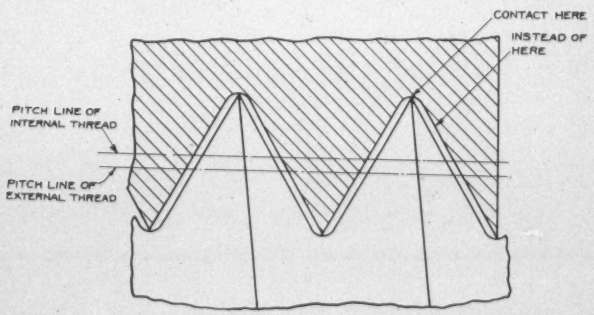


FIG. 9—ASSEMBLY OF TAPPED HOLE AND SCREW CUT WITH "V" TOOLS WHICH HAVE LOST CREST OF THREAD.

Stud Fits. The accompanying table covers complete limits but the important point is the reduction of the outside diameter of the screw providing clearance for the flow of metal from the interference fit. The clearance at the crests of the thread must not be filled at either major or minor diameter, or the stud will gall.

STUD FIT SPECIFICATIONS

All dimensions are inches unless otherwise indicated

Nominal Size	¼-20	5/16-18	⅜-16	7/16-14	½-13	9/16-12	⅝-11	¾-10	⅞-9	1-8
Basic Thread Depth	.0325	.0361	.0406	.0464	.0500	.0541	.0590	.0650	.0722	.0812
Basic P.D.	.2175	.2764	.3344	.3911	.4500	.5084	.5660	.6850	.8028	.9188
Basic Major Dia.	.250	.3125	.375	.4375	.500	.5625	.625	.750	.875	1.000
Basic Minor Dia.	.1850	.2403	.2938	.3447	.4001	.4542	.5069	.6201	.7307	.8376
*P.D. Stud	.221 .2195	.2804 .2789	.3389 .3374	.3956 .3941	.455 .453	.5139 .5119	.572 .570	.691 .689	.8088 .8068	.9248 .9228
P.D. Hole	.219 .2175	.2784 .2764	.3369 .3344	.3936 .3911	.4525 .4500	.5114 .5084	.569 .566	.688 .685	.8058 .8028	.9218 .9188
Stud Fit Tight	.0005 .003	.0005 .004	.0005 .0045	.0005 .0045	.0005 .005	.0005 .0055	.001 .006	.001 .006	.001 .006	.001 .006
Major Dia. Stud	.244 .240	.3065 .3025	.369 .365	.4315 .4275	.494 .490	.5565 .5525	.619 .615	.744 .740	.869 .865	.994 .990
Min. Major Dia. Hole	.251	.3135	.3765	.439	.5015	.564	.627	.752	.877	1.003
Min. Clear Major Dia.	.008	.0085	.008	.008	.009	.009	.009	.009	.009	.010
Max. Minor Dia. Stud	.1885	.2443	.2983	.3492	.4050	.4598	.513	.626	.7366	.8436
Tap Drill or Minor Dia. Hole	.201	.261	.3125	.368	.422	.484	.531	.656	.765	.875
% Full Thread	75	71	72	75	72	72	79	72	76	77
Min. Clear Minor Dia.	.013	.019	.0125	.011	.015	.024	.014	.029	.027	.025
Major Dia. Tap	.255 .254	.318 .317	.381 .380	.4445 .4435	.5075 .5065	.570 .569	.633 .632	.759 .7575	.885 .8835	1.011 1.0095
Wear Limit	.252	.315	.377	.440	.503	.5655	.628	.753	.878	1.004
P.D. New Tap (Precision Ground No. 1 Limits)	.218 .2175	.2769 .2764	.3349 .3344	.3916 .3911	.4505 .4500	.5089 .5084	.5665 .5660	.6855 .6850	.8033 .8028	.9193 .9188
Max. Minor Dia. Die	.1885	.2443	.2983	.3492	.4050	.4598	.5130	.6260	.7366	.8436
*P.D. New Die	.221	.2804	.3389	.3956	.455	.5139	.572	.691	.8088	.9248
*Min. Thd. Engaged Double Depth	.039	.0415	.0525	.0595	.068	.0685	.084	.084	.100	.115

*Use Acorn dies to make Stud to close limits.

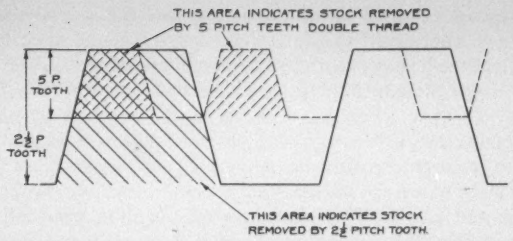

THIS AREA INDICATES STOCK REMOVED BY 5 PITCH TEETH DOUBLE THREAD
5 P. TOOTH
2½ P TOOTH
THIS AREA INDICATES STOCK REMOVED BY 2½ PITCH TOOTH.

FIG. 10—COMPARISON OF STOCK REMOVED BY DOUBLE AND SINGLE THREAD OF SAME LEAD.

Multiple Threads. The average user of taps and dies seems to dread multiple threads, just why, we do not know. It might be inherited from the olden days when chalk marks on the face plate and headstock indicated when to catch (or miss) the multiple thread with the threading tool. At any rate there is much to be gained by using multiple threads, such as double, triple, and quadruple, according to the application as will be seen in the following illustration.

A customer is using an elevating screw 1¼-in. in diameter and desires the nut to raise or lower .400 in. per revolution which is equivalent to 2½ pitch. Should he use 2½ pitch single or 5 pitch 2½ lead double thread? In Fig. 11 we show a 10 to 1 enlargement

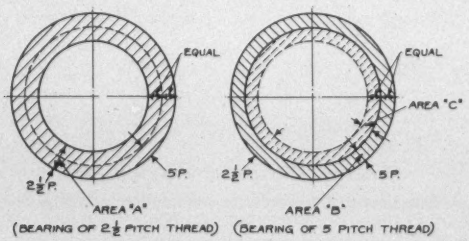


FIG. 11—COMPARISON OF BEARING OF DOUBLE AND SINGLE THREAD OF SAME LEAD. Cross-sections of both screws emphasize the respective bearing areas. It is obvious that a 2½-pitch thread is twice as deep as a 5-pitch thread; also that area A equals area B plus area C and that area B is greater than area C. Therefore, twice area B is greater than area A and the 5-pitch double thread gives greater bearing area due to the larger minor diameter (in this case 17% more bearing).

of a 5 pitch 2½ lead double Acme thread superimposed upon a 2½ pitch single Acme thread and for simplicity we are showing the Basic Outside and Minor Diameters only. Note that twice as much metal must be removed when using the single thread in place of the

double thread. Fig. 12 shows the gain in bearing area of the double thread over the single thread. I do not advocate square threads because additional advantages are gained when using Acme or 60-deg. National form threads and the area conditions are the same.

Pipe Threads. Pipe threads are used for many purposes and under a wide range of conditions so that it is necessary to clearly define the requirements for other than National Taper Pipe (N.P.T.) for which there is a recognized standard of thread limits for product, taps, dies and gages. The most common variation from standard is to use a straight pipe tap to thread the hole which is to be assembled with a taper thread on the pipe. The National Straight Pipe Tap has a basic pitch diameter the same as at the gage notch with a plus or minus tolerance and the hole is properly gaged with the taper plug plus or minus the notch the same as a taper hole, and this fit is suitable for *low pressure steam*, water, etc. See Figure 12.

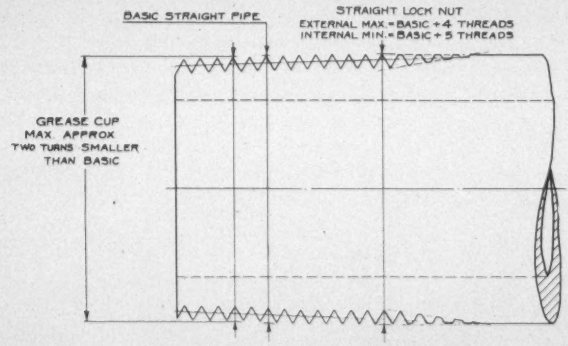


FIG. 12—PIPE THREAD RELATIONSHIP.

The holes for *grease cups* and fittings are tapped with a grease cup tap which is straight and has a maximum diameter at two turns below the gage notch size. The crests of the threads are flatted on both taps and dies for this specification. For applications where both parts are made with straight thread, the straight pipe gages which are basic notch sizes are regularly used. The straight pipe taps used for this work should have their tolerances taken all plus.

American National Fire-Hose Coupling Threads. Wide variations in thread dimensions and types of couplings for fire-hose connections, have from the beginning contributed all too liberally to heavy losses in human lives and property values, incident to the

spread of many of our most disastrous fires. So that the urgent need of one uniform or standard thread for all fire-hose couplings, hydrant outlets, and special fittings has been generally recognized for a great many years.

Municipalities and manufacturers installing or producing fire-fighting appliances are continually making inquiries regarding a standard for fire-hose coupling threads and in many states the cities and towns are joining in statewide movements to change their existing threads to agree with the national standard. Much of this increased interest and concern is due to recent accomplishments under the leadership of the National Board of Fire Underwriters.

It has heretofore been the practice of most of the manufacturers to cut the threads on fire-hose couplings and fittings in a lathe, by setting the cutting tool so as to reproduce sample threads of new or old fittings submitted with the orders or to use thread templets previously made up. Obviously this method of manufacture, if pursued for any length of time, would result in widely different threads, frequently none-interchangeable with others in the same city or town and with supposedly like threads in other municipalities.

When the new order prevails, however, couplings and fittings will be ordered by the simple phrase "2½-, 3-, 3½-, 4½-inch National (American) Standard Fire-Hose Coupling Screw Thread." This standard is fully described in a pamphlet known as the "National (American) Standard Fire-Hose Coupling Screw Thread," a copy of which may be obtained on application to The American Standards Association, 29 West 39th Street, New York City. This will permit the manufacturer to cut these threads with standard taps and dies, which will insure complete interchangeability and will reduce to a considerable extent the cost of production. When fire-hose threads are made in this way, the manufacturer's inspector will check the product by standard steel ring and plug inspection gages. If moderate care is exercised in the use of these gages and they are replaced when worn beyond the allowable limits, all the product passed by them will surely pass the field inspection gages with which the fire chiefs, waterworks superintendents and other users are providing themselves.

As shown in Fig. 13, the thread gages consist of a "Go" and a "Not Go" plug-thread gage for the coupling swivels (internal thread) and a "Go" and a "Not Go" ring-thread gage for the nipples (external thread). The "Go" plug and ring-thread gages make sure that all the parts will go together, while the "Not Go" plug and ring-thread gages insure that the parts will never be too loose.

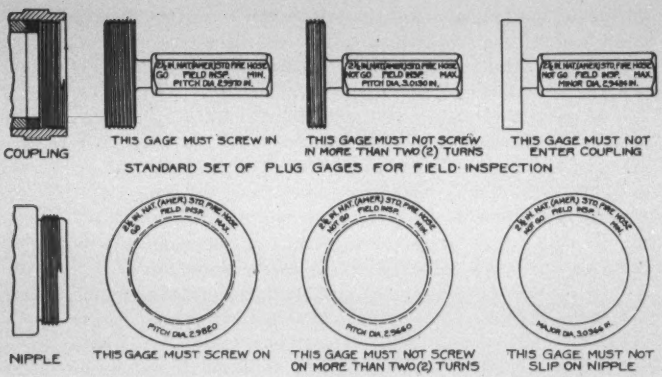

COUPLING
THIS GAGE MUST SCREW IN
THIS GAGE MUST NOT SCREW IN MORE THAN TWO (2) TURNS
THIS GAGE MUST NOT ENTER COUPLING
STANDARD SET OF PLUG GAGES FOR FIELD INSPECTION
NIPPLE
THIS GAGE MUST SCREW ON
THIS GAGE MUST NOT SCREW ON MORE THAN TWO (2) TURNS
THIS GAGE MUST NOT SLIP ON NIPPLE

FIG. 13—STANDARD SET OF RING GAGES FOR FIELD INSPECTION OF AMERICAN NATIONAL FIRE-HOSE COUPLING THREADS.

In order that the depth of engagement of the threads be sufficient, the minor diameter of the coupling swivel (internal thread) should be checked with a "Not Go" plain cylindrical plug gage, made to the dimension specified for the maximum minor diameter of the coupling. The major diameter of the nipples (external thread) should also be inspected with a plain ring gage, made to the dimension specified for the minimum major diameter of the nipple. The "Not Go" plug and ring plain cylindrical gages insure that the height of the thread in each case is within the limits set by the national standard.

EXPERIENCES IN WATERSHED SANITATION

BY MARSHALL S. WELLINGTON*

[*Read May 12, 1938.*]

The watershed of the New Haven Water Company, as now developed, consists of 96.6 sq. miles. The Company owns the shores of all the reservoirs and the banks of the main brooks feeding into the reservoirs on most of the supplies. The topography of the land automatically divides this area into nine smaller watershed districts. These smaller districts are in charge of a caretaker or foreman, who has a varying number of men under him according to size of district. These men are trained to look for unsanitary conditions and are always alert for them when going about their other duties on the watershed. In addition to these men, we have a special constable who covers the whole watershed and is on the look-out for bad conditions. I, myself, cover the entire shed twice a year on a regular sanitary inspection. One of these inspections is made with a representative of the Connecticut State Department of Health. Every day, different parts of the watershed are seen by me while my other duties carry me hither and yon. Other members of the company are always alert to sanitary conditions when they travel over the different sheds. Other sources of information are the various health officers of the towns in which the watersheds are, and people who either have an ax to grind with a neighbor, or who have our interests at heart.

Patrol of Watersheds. I believe that a constant patrol of a watershed is the one most important factor in maintaining a sanitary watershed. A regular patrol is not necessary, but one of sufficient intensity to keep the inhabitants and transients watershed-conscious. This patrol keeps new sources of pollution reduced to a minimum and also keeps old sources from springing into flame again.

Two illustrations will clarify this point. A reservoir was taken out of active service but was retained in reserve. Word travelled with lightning speed that this reservoir was not being used. This meant to most of the people on the watershed that all sanitary barriers were down. It required some convincing to have the sanitary conditions kept as they were. This slacking up of care would not have been found if a patrol had not been kept.

A pig pen of about a hundred pigs was located on one of the

*Sanitary Engineer and Superintendent of Chlorination, New Haven Water Company, New Haven, Conn.

brooks flowing into a reservoir. After many conferences the water company drilled a well and furnished a pump so that the pigs in a new location could have water. On one of the semi-annual inspections the pigs were found back on the brook. When the owner of the pigs was asked why this was so, he informed us that the pump handle was broken and as the pigs had to have water he moved them back on the brook. The owner of the pigs had to be threatened with a law suit before he would buy a new pump handle and move the pigs back. This shows that unsanitary conditions can never be considered closed.

Abatement of Nuisances. When a bad condition is reported to me the usual method of procedure is to have the foreman, in whose district the complaint lies, visit the property owner or tenant and talk with him. This approach has a personal and friendly aspect, as usually the foreman and property owner or tenant are personal friends. If no progress is made in this manner or if the owner lives in some other section of the country, or if the problem of correcting the unsanitary condition is out of the ordinary, I call on the person and try to sell him the idea of his fixing up the trouble. My salesmanship is not always successful, in which case a copy of the "Rules and Regulations" of the State Department of Health is left with him for his consideration. If no action on his part is then forthcoming, the next step is to visit him with the Health Officer or an Engineer from the State Department of Health or both. If no action is then taken, an order is issued him by the Health Officer to abate the trouble. This is very seldom necessary, for which I am very thankful. In the few cases where orders have been issued, the conditions have been remedied before the time limit in the order has expired.

I wish to digress a little at this point to thank Mr. Warren J. Scott, Director, Bureau of Sanitary Engineering, State Department of Health, and his assistants, for the whole-hearted coöperation which they have given us when called upon. Their aid has certainly made the sanitation of watersheds much easier.

Types of Unsanitary Conditions. Unsanitary conditions may come from the following: Construction work, circuses, automobile parkers and picnickers, pigs, dumping, industrial wastes, milk wastes, outdoor closets, sink drains, cesspools, and septic tanks. This is a rather comprehensive list, but it by no means includes everything that enters into the question. Let us take up the items in the foregoing list and see what bearing they have on watershed sanitation. Some can be passed over without much comment while others will require more discussion.

Construction Work. Under construction work come such things

as building culverts, bridges, electric and telephone conduits, and roads. Probably the last is the most important. The workers on these projects must be given some place to use or they will create very unsanitary conditions on the banks of streams. The privies for their use must not be over 200 ft. apart, or they will not use them. If they are farther apart than this, the workers will not use them if they can find a place nearer. On every job, the foreman must be advised of the care to be taken. It does not make any difference if it is the same foreman that has been advised before; he will not take the proper care unless spoken to about the job that he is on. Even after the foreman has been advised as to the care to be taken, the job must be checked every once in a while to see that conditions are as they should be. I have seen workers fired because they have not lived up to the rules that have been laid down. It is sometimes possible to have a sanitary code written into a contract, which is a great help.

Circuses. The circus grounds of New Haven are very close to the shores of one of the reservoirs. The boundary line has to be patrolled from the time the first unit of the circus arrives until the last one leaves. This is necessary to keep the spectators, roustabouts and performers from committing a nuisance too near the reservoir. The need of this can be plainly seen if one stops to consider the typhoid fever epidemic that one of the circuses had a few years ago.

Parking and Picnicking. Automobile parkers and picnickers create a nuisance by leaving behind them refuse of all kinds, which, if nothing else, is very unsightly. This form of trouble has been very nearly eliminated by the patrols advising the parties that they are on the watersheds and asking them to be sure to leave no rubbish behind them when they leave. The people in these parties do not like to be interrupted, so the news spreads by that mysterious underground telephone that they are not wanted and will be interrupted if they come. As a result, they seem to be going elsewhere. A hazard of this type that has no great significance in the sanitary field, but does in the economic, is that of fire. An incidence along these lines happened to me some time ago, while riding across the watershed. A picnic had been held on a brook, and they had left behind them bread, fruit skins, watermelon rinds, papers, etc. A short distance beyond this place a second picnic party was in progress. I spoke to them in as friendly a way as I knew how, but was called names not fit to print. I asked the men in the party if they had a few minutes to spare as I would like to show them something. I took them to where the other party had been, and one look was enough for them.

They apologized for all the things they had called me. This ban on automobile parkers and picnickers is a case where a great many suffer for the errors of a few.

Dumping. Dumping rubbish in brooks is bad enough, but when it comes to dead animals that is something else. Of late years the number of dead horses and cows have been very few and far between. Maybe we have the farmers educated. Maybe they do not like the experience of getting a decayed animal out of a brook. We can usually find the one responsible for putting the animal in the brook, and he has to take it out. Maybe the fat-rendering companies make it worth the farmer's time to turn the dead animal over to them. Whatever the cause for the decrease, we are thankful for it. A short time ago one of our men while out with a crew working on pine trees, wandered down to a brook in the neighborhood, just to have a look at the brook. He saw two boxes in the brook and on fishing them out he found that they contained the skin, hoofs, horns and entrails of a deer. Here is another illustration of what a patrol will do. There was no reason for the man to go to the brook except his desire to see that everything was as it should be.

What is the urge and what is the excuse for putting materials in a brook? For the urge just consider yourself. How many times have you, when driving in an automobile, carried for a considerable distance something you wished to throw away, until you found a brook? Most of you know the hazard. What urges you, urges them. The excuse offered is that running water purifies itself in a certain distance. This distance according to popular concept is anywhere from 15 to 100 ft. This of course is an old idea and is where an educational program can do a great deal of good. I was beginning to feel that when the younger generation grew up, this problem would be over. Not long ago I was talking with a lady about the leaching cesspool of the septic tank for her house. I was trying to make her see that 30 ft. to the stream was too short a distance, and that the leaching cesspool should be moved farther back. Her answer was that it made no difference as water running over the ground for 10 ft. purified itself. On asking where she obtained that idea, she advised me that her daughter had learned it in high school. She further advised me that her daughter had said not to mind what anyone else said, she was right. Such faith in daughter! Such faith in teacher! We shall still have to keep up the educational work.

Piggeries. Whenever a person decides he wants to keep pigs, the first thing he does is to go out and find a brook. He will then build a pen on the brook or on the bank so he can keep the pen

somewhat dry by draining it into the brook. This problem is one of the worst to get cleaned up, as most of the people are foreigners and do not understand English very well. Here is a situation where the State Department of Health assists us. When one of the engineers speaks to the owners they feel that maybe we are not trying to put something over on them. Even after the pigs are removed, a watch has to be kept to see that they are not put back, as the first part of this paper shows. Patrol once again.

Industrial Wastes. Industrial wastes, with the exception of milk, cause very little trouble. As soon as the nuisance is called to the attention of the officials of the company, steps are taken to fix it. Milk wastes from small dairy farms, with 15 to 30 head of cattle, are a problem. First, milk is difficult to put in a form easily disposed of. Second, the area of ground for disposal is limited in most cases. Third, the nature of the soil is very poor for seepage. Fourth, the capital of the farmer is limited, so that an elaborate disposal plant cannot be built. I have found that the best solution is to build a cesspool about 5 ft. in depth by 5 ft. in plan, understanding that another will be built when the first fills up. This is the cheapest thing for them to do, as there are plenty of stones handy for the walls of the cesspool and almost anyone can dig a hole in the ground and stone it up. I have found that a septic tank is of no material advantage and that a blind cesspool is useless. I have the feeling that after a cesspool has filled up and been abandoned, that if left standing idle for a few years it can be used again. Time alone will answer this.

Domestic Wastes. Domestic wastes are the greatest problem that we have to deal with. This can be divided into three parts: disposal of sink waste; disposal of human excreta, where there is no inside toilet and no running water; and disposal of human excreta where there are running water and inside toilets. Sink drains are either allowed to flow on the surface of the ground or are piped to a brook. Here again is the question of running water purifying itself. The sink-drain waste is most easily taken care of by means of a small cesspool; usually 3 ft. deep by 3 ft. in plan suffices. It should be understood, however, that when it fills up another will be dug. An ideal situation would be the installation of a grease trap before the cesspool. The drawback to the grease trap is its proper care. Most people will not clean it often enough, or if they clean it they empty it in the brook. Unless you are sure that the grease trap is to have proper care, it is best to forget it.

The outside closet can be at fault by being too near a brook—sometimes over a brook—or the pit can be too shallow. To my way

of thinking the closet should be set over a deep pit, and when this is nearly full the closet should be moved over a new pit and the old one filled in. For some unexplained reason, people do not like to move the closet even 5 ft. If a closet is to be between 50 and 250 ft. from a brook, a tight concrete vault should be used. The closet should rest on this vault so that the vault is easily accessible for cleaning, and at the same time care should be taken to keep rain water out. The roof of the closet should not slope towards the clean-out cover. When a perfect closet has been built, the troubles are not over, as the cleaning has to be watched. Running water and inside toilets mean septic tanks and more grief. I will not go into detail about the construction of septic tanks and means of disposing of wastes from them, as there is a great deal of good literature about it. I do wish to say that from my experience a leaching cesspool is far superior to a tile field, easier and cheaper to build, and, above all, more adaptable to a restricted place. For a new house and plenty of ground, a tile field drain is probably best.

I find there are three major difficulties in dealing with septic tanks. First, the false impression that the majority of people have about the functioning of septic tanks. They have been told that all they have to do is to install a septic tank and their troubles are over. In some mysterious manner, the waste that enters the tank disappears. If any does leave the tank, it is fit to drink. An educational program has to be started, particularly on the necessity of cleaning septic tanks. I advocate cleaning every three years. This does not go so well with most people, and they let them go until they plug up and a new cesspool or field drain has to be built. As usual, experience is the better teacher. Second, the steel tanks sold by mail-order houses and other people are big offenders. These are usually cylindrical tanks stood on end, without baffles or seals on the inlet or outlet, so that there is very little settling effect. Third, the makeshift affairs installed by speculator builders and unscrupulous plumbers. Get the system covered up and then let the buyer hold the bag, seems to be their slogan. A recent experience will well illustrate this. A septic tank was recently giving trouble after being in service a year and a half. On digging it up to see what was wrong, it was found that the septic tank had two compartments made by using half a barrel as a form. The inlets and outlets were sealed by pipes turned down, which was satisfactory. The joker was that each half only had a capacity of 45 gal. or a total of 90 gal. A septic tank for this place needed a capacity of 350 gal. To take waste away from this tank, there was a blind cesspool 3 ft. deep by 3 ft. sq. The

plumber had charged the people enough to put in an adequate system. I wish I could say that this is the exception rather than the rule, but I cannot. Every installation may not be as bad as this, but a little more care is needed a great many times. Even where a satisfactory tank is laid out by engineer or architect, they must live on the work to see that it is made as laid out.

My method of procedure, when new construction has been reported, is to visit the place and talk to the builder, advising him as to the sanitary code of the State Board of Health, and maybe making a few suggestions. I then follow this by a letter containing a copy of the code. This is done so that at a later date, if trouble arises, they cannot say "I did not know it." It is too bad that they cannot be stopped before they start. Some of the towns in the watershed have codes governing septic tanks, but they are not enforced as they should be.

When the code of the State Department of Health went into effect on July 1, 1925, the New Haven Water Company decided that they would obtain the goodwill of the people whom this code affected by helping them abide by it. We installed or helped install all the necessary sanitary appurtenances. This move just delayed our grief, for they have expected us to maintain them. We are digging our way out of this secondary reaction and hope soon to be in the clear. A word of warning to all—have it thoroughly understood that the maintenance of the sanitary appurtenances is a duty of the property owner.

The question sometimes arises as to whether a seepage of water from the ground is from a septic tank or, if there is more than one in the vicinity, which one it is coming from. If the flow is large, it can sometimes be determined by filling the bath tub in the house and then emptying it at the same time as flushing the toilet. This large volume of water may increase the amount of water running out of the ground. Another method to check this seepage is to put a little uranine dye in the toilet or tub and then watching for it over a period of a day or more.

A few years ago we had trouble with one of the reservoirs showing a rather high count of the coli-aerogenes group. Samples were taken for bacterial analysis of the brooks entering the reservoir. A sanitary survey of the offending brook revealed no cause for the high concentration of this group. Fortunately it was possible to divert this brook.

Summary. I believe that of the great number of ramifications necessary for better sanitary conditions on a watershed, the five most important are.

1. A program of establishing a patrol of sufficient magnitude to keep the people watershed conscious.

2. A program to educate the people that only under certain conditions, not generally found, does running water purify itself sufficiently to be safe for drinking purposes.

3. A program to educate the people as to the proper functions of septic tanks.

4. A program to curb unscrupulous plumbers and building speculators from installing inadequate sanitary disposal systems.

5. A program to educate the people that they are responsible for maintaining the sanitary conditions on their property.

Summary of Discussion.

Mr. C. P. Moat* called attention to the need for educating the public relative to the hygienic limitations of septic tanks and to the need for maintaining friendly relations with the property owners on watersheds. He concurred with the author that sanitary control of the transient population on watersheds presented a most difficult problem. It was his opinion that on certain watersheds the care of out-door privies was best placed under the direct supervision of the water department.

Mr. Francis H. Kingsbury† believed that in spite of rules and regulations for the protection of watersheds water departments would find it more satisfactory to perform the work of privy and cess-pool control themselves rather than to rely upon the householder's obedience to such rules and regulations or to the enforcement by law.

Mr. Leonard W. Traeger** stated that chlorination should be employed to safeguard surface water supplies, even in remote regions, against chance pollution by transients.

Mr. F. O. A. Almquist and Mr. Warren J. Scott‡ mentioned the practice of water departments of paying a reward for reporting cases of intestinal disease on the watershed. Mr. Wellington in closing stated that the cleaning of outhouses and cess-pools by the water department was tried at New Haven but abandoned because of the expense involved.

*Vermont State Board of Health.
†Massachusetts State Department of Health.
**New Hampshire State Board of Health.
‡Connecticut State Department of Health.

CONNECTICUT'S NEW PLUMBING REGULATIONS AS AFFECTING WATER SUPPLIES

BY LESLIE K. SHERMAN*

[*Read April 14, 1938.*]

The Connecticut Legislature, during its 1937 session, passed an act requiring the State Department of Health to draw up a code of "minimum requirements for drainage and toilet systems." Consequently, a set of minimum plumbing requirements was approved by the Public Health Council in December 1937 and became Regulation 127 of the State Sanitary Code.

The sections of this regulation are in accord with the "basic plumbing principles" of the so-called Hoover Code, "Minimum Requirements for Plumbing in Dwellings" recommended by the United States Bureau of Standards. The regulation was also drawn to comply with existing state statutes. Several sections of the regulation were written to cover specific hazards to drinking-water supply systems and to include drinking-fountain design.

Some sections particularly of interest to waterworks men are:

a. Plumbing and drainage systems shall be so constructed as to avoid contamination of safe drinking-water supplies in houses or buildings. There shall be no cross-connections between such safe water supplies and unsafe water supplies, nor shall such safe supplies be piped to refrigeration, air conditioning or other mechanical equipment provided with direct connections to drains or constructed in such a manner as to permit contaminated water to be siphoned or drawn into the water supply pipes.

Storage of drinking water in buildings shall be only in covered tanks so constructed as to avoid any possible contamination of the water in the tanks. Sewer or waste lines located above storage tanks and direct overflows and drains to sewer systems are expressly prohibited.

b. Buildings in which water-closets and other plumbing fixtures exist shall be provided with a supply of water adequate in volume and pressure for flushing purposes.

c. The pipe system shall be of sufficient size to supply water for adequate flushing of toilet fixtures without unduly reducing the pressure at other fixtures.

d. Devices for heating water and storing it in "boilers" or hot-water tanks, shall be so designed and installed as to prevent all dangers from explosion.

t. No plumbing fixture nor waste outlet shall be installed which will provide a cross-connection between a distributing system of water for drinking and domestic purposes and a drainage system, soil, or waste pipe and permit or make possible the back-flow or siphonage of sewage or waste into the water supply.

*Assistant Sanitary Engineer, Connecticut State Department of Health, Hartford, Conn.

Note: Attention is directed to the danger from under-rim water inlet fixtures and flushometer valves without adequate vacuum breakers.

u. All new drinking-fountain installations or replacements shall be constructed with a slanting jet issuing from a nozzle of non-oxidizing impervious material with a non-oxidizing guard to prevent the mouths and noses of persons using the fountain from coming in contact with the nozzle. The jet shall be located so as not to touch the guard and shall be discharged at such an angle that the water can neither fall back nor be forced back onto the point of discharge. The fountain jet and all openings in the water supply piping shall issue above the level of the fountain bowl. The drainage from the bowl shall be adequate and so constructed as to prevent fouling of the bowl. The drain from the fountain shall not have a direct physical connection to a waste pipe unless the drain is trapped. The waste opening and pipe from the fountain shall be of sufficient size to carry off the water promptly. The opening shall be provided with a strainer.

These sections call the attention of plumbers to possible dangerous conditions that may exist in interior water supply systems and should thereby prevent inter-connections in plumbing fixtures, in mechanical equipment and in storage tanks, with the attendant dangers of back siphonage. Protection of drinking-water storage and cooling tanks in buildings, which has not in the past received so much attention as deserved, is also required.

A supply of water adequate in volume and pressure at all fixtures, as required by Sections (b) and (c) of Sanitary Code Regulation 127 is obviously essential to maintain sanitary conditions and reduce the chances of vacuum formation in the water piping.

Section (d) concerning explosion hazards of hot water tanks is also of importance to the water user.

Section (t) is intended to prevent future installation of plumbing fixtures permitting back flow or siphonage of sewage or waste into the water supply. Under-rim water-inlet fixtures and flushometer valves without adequate vacuum breakers are specifically mentioned to emphasize these hazards. Under-rim water-inlet fixtures may be considered to include vats and wash tanks in industrial plants. Many such vats contain dangerous chemicals and frequently are provided with a continuous flow of water, thus presenting a serious hazard. Submerged inlets are sometimes considered a necessity in these vats and in such cases an adequate air break or siphon preventer must be provided.

Various Types of Inter-Connections

The hazards of direct cross-connections between piping carrying potable water and systems carrying water from unsafe or doubtful sources are quite generally realized. There are other types of inter-

connections which under certain conditions may be equally dangerous. For example, the direct connection of a water line to a sewer is of little danger under normal conditions, but in the event that a vacuum is created in the water supply system some dangerous material may be drawn from the sewer. Valves, checks, or similar devices may not function properly all of the time, and it is unwise to place complete dependence in them.

Connections of this type are frequently found in use for cooling through compressors used for air and in connection with refrigeration equipment, and through condensers. Compressors and condensers are becoming more prevalent with the installation of air-conditioning equipment. The discharge lines from such devices should waste above the maximum flow line of sinks, sumps, or tanks. These structures may then be trapped and connected to a sewer.

In addition to the connections in air conditioning equipment just mentioned, there is another type of connection which is frequently overlooked. Water sprays may be used for air washing or precooling, and these sprays are often supplied by a circulating system consisting of a pan to receive the spray water and a small circulating pump drawing water from the pan and discharging to the spray nozzles. Make-up water is provided from the public supply through a float operated valve, usually on a submerged inlet. The water in the circulating system may become very dirty. It is understood that in large installations buckets of mud are frequently removed from air washers. The possibility of back siphonage of this dirty water should be prevented. It is usually a simple matter to raise the inlets above the maximum water level.

Drain connections of sprinkler systems are sometimes made to sewer lines. These direct connections are undesirable and should be avoided.

Water-operated cellar drainers may permit back siphonage of dirty water, unless equipped with vacuum breakers.

Storage Tanks in Buildings

Storage of drinking water is necessary in buildings extending above the elevation reached by water under normal public supply pressure, and may be provided in others. Drinking-water tanks in which the water is cooled by refrigeration equipment are also frequently used.

Pressure tanks present fewer hazards than those open to the atmosphere, but drains from these should not be connected directly to sewers. Tanks under only atmospheric pressure may be con-

taminated in several ways. Covers for such tanks may not be tight or sections of covers may be left off, permitting the entrance of dust, dirt, or other foreign matter. If sewer or waste lines are located above such tanks, as sometimes occurs when sewers are carried along basement ceilings, the danger is greatly increased, as any leakage might drop into the drinking water. Connecticut's new Sanitary Code regulation requires these tanks to be tightly covered and prohibits sewer or waste lines above them. Direct connections of drains and overflows from tanks to sewer lines are dangerous, especially so if the tanks are located in basements.

Tanks storing water for use in lavatories and toilets are not uncommon. As people might sometimes drink water from washroom taps, such tanks should also be protected from contamination. Frequently these tanks are not considered as sources of drinking water by building managements, and the hazards need to be pointed out to them.

Water-supply inlets to all storage tanks for fire, process work, hydraulic elevators or other purposes should be above the overflow level to make back-siphonage impossible.

Recent Connecticut Surveys of Interior Water Storage

Many water works superintendents may believe that few such hazards from cross-connections with other water supplies or interconnections with sewers or drainage systems exist in their cities, but in the five largest Connecticut cities, where surveys of interior water piping are now being carried on, numerous objectionable conditions have been found. In most of these cities, the water departments or companies have always been alert to the dangers of the usual types of cross-connections, and plumbing inspectors are employed.

The surveys mentioned have been undertaken by the city health departments in Hartford, New Haven, Bridgeport, Waterbury and New Britain. The State Department of Health has instigated the surveys, and inspectors of the local health departments have been instructed in the manner of survey. The local inspectors are carrying out these surveys along with their regular work. It is planned that these men will inspect all buildings over three stories in height, all stores over one story, and all hotels, theatres, hospitals, and factories. As it does not seem feasible to attempt to inspect all buildings, those mentioned were considered most likely to present hazards. Considerable time will be required to complete the surveys as planned, because no additional personnel has been provided for the work. It is planned later to extend these surveys to other cities and towns.

The primary objective of the surveys is to insure proper protection of drinking-water storage tanks, but a questionnaire prepared for the inspectors includes leading questions intended to assist in locating undesirable connections that might affect the drinking water. It is not feasible to inspect all plumbing fixtures, but it is felt that much is being accomplished in the elimination of major hazards.

In the course of the recent interior water-piping survey in one city, three tanks were discovered that were used for cooling drinking water which were not adequately covered and were located under sewer lines along basement ceilings. Two of these tanks had drains and overflows directly connected to sewers. If, during a storm or because of clogging, the sewer had backed up or flowed under a head of 3 or 4 ft., sewage would have entered the drinking water. Such a condition, if temporary, might not be discovered until illness resulted. In a factory employing a large number of people, a serious epidemic might be the result.

Of the tanks mentioned, two have since been protected by covering, removal of overhead sewer lines, and disconnecting drains and overflows from the sewers, and the use of the third tank has been abandoned and individual fountain coolers have been installed.

Up to April 1, 1938, a total of 458 buildings has been inspected in the cities mentioned. The accompanying table partially summarizes the conditions found, according to inspection reports from the local health departments:

CITY	NUMBER OF BUILDINGS INSPECTED	NUMBER OF DRINKING-WATER TANKS	NUMBER OF DRINKING-WATER TANKS NOT PROPERLY PROTECTED	NUMBER OF DIRECT CONNECTIONS TO SEWERS	NUMBER OF SUBMERGED INLETS TO TANKS HOLDING NON-POTABLE WATER	NUMBER OF CROSS CONNECTIONS WITH OTHER WATER SUPPLIES	NUMBER OF CONDITIONS IN NEED OF IMPROVEMENT
A	113	29	10	10	4	0	24
B	128	52	8	5	10	1	24
C	31	4	3	15	7	0	25
D	159	0	0	0	11	1	12
E	27	2	0	1	16	3	20
Total	458	87	21	31	48	5	105

It is evident from this tabulation that many conditions in need of improvement have been found. Many situations that might be dangerous have already been taken care of. The findings cited in the table may be more or less typical of cities of similar size, i.e., with populations from 50,000 to 170,000.

SUMMARY

Connecticut's new plumbing regulations should prevent future installation of water-piping systems subject to the hazards previously mentioned, specifically, inadequately protected drinking-water storage tanks, direct connections to sewers, plumbing fixtures and devices subject to back siphonage, improperly sized piping-systems in which vacuums may be formed, and cross-connections.

The interior water-piping surveys undertaken in connection with the regulations are bringing about the elimination of many existing dangerous conditions. It is felt, therefore, that the chances of the safe water delivered by the public system becoming contaminated between the curb and the consumer are being materially reduced in Connecticut. Water works officials should be vitally interested in the quality of water reaching the consumer, and they can be of considerable assistance by coöperating with other local agencies in locating and eliminating hazardous fixtures or connections. To quote from the title of a recent paper by L. H. Enslow, effort should continually be made by all agencies concerned to "Keep Good Water Good."

DISCUSSION

Stephen H. Taylor.* The author's paper is very interesting and convincing, and the State of Connecticut is to be congratulated on realizing and doing something about the dangerous conditions that exist in interior water supply systems. It recognizes not only the larger cross-connections between public supplies and unprotected private supplies, but also inter-connections in plumbing systems, in mechanical equipment, and in storage tanks with the attendant dangers of back-siphonage from direct connections to drains and sewers. The author's discussion of these rules brings out very clearly the need for their enforcement in order that the water supply delivered at the faucet shall be ample and fit for drinking. The conditions he reports are typical of those which would be found in any community.

This is an extremely interesting and timely subject. Many public health and water supply organizations are now giving a great deal of attention to this subject as evidenced by numerous articles in their publications for the past few years.

The Department of Public Health of Massachusetts, in 1937, adopted rules and regulations covering cross-connections between public water supplies and fire and industrial supplies. It is to be regretted that

*Superintendent of Water Works, New Bedford, Mass.

these rules did not include protection against inter-connections in interior plumbing systems as was done in Connecticut.

A few other states have recognized these dangers and have passed corrective legislation. I believe similar action should and eventually will be adopted by every state in the Union which has due regard for the health of its citizens.

The large percentage of dangerous fixtures and conditions found wherever careful inspections have been made proves beyond question the necessity for better supervision of interior piping and fixtures to avoid the serious consequences of dangerous installations, particularly in hotels, public buildings, hospitals, etc.

"Water Works Engineering" in its issue of March 16, 1938 contains an interesting account of an inspection of plumbing made under the direction of Arthur P. Miller, Sanitary Engineer-in-charge, Interstate Sanitary District No. 1, U. S. Public Health Service, made between May 1936 and June 1937. It covered 810 Federal structures in New York City and 96 in Detroit, Michigan. In New York City, 21,928 fixtures were inspected and 14,844 or 67.7% were disapproved. In Detroit, 2,736 fixtures were covered and 2,052 or 75% disapproved. Residences, office buildings, multiple apartments, hospitals, barracks and dormitories were included in this survey. Those buildings not falling in one of these headings were included as unclassified and constituted about 50% of the total number examined.

Willis E. Collins of the State Department of Public Health of Texas in a thesis prepared as part of his graduate work at the Harvard Graduate School of Engineering, 1936-1937, investigated over 800 bathtubs and lavatories made by 14 different manufacturers and found that of 483 bathtubs 58% had unsatisfactory water inlets and 50% had unsatisfactory drainage outlets. Of 396 lavatories, 60% had unsatisfactory water inlets and 3% unsatisfactory drainage outlets.

In a paper entitled "A Survey of Potential Health Hazards Due to Faulty Plumbing" by W. Scott Johnson, Sanitary Engineer, Health Division, St. Louis, Mo., published in the JOURNAL OF THE AMERICAN WATER WORKS ASSOCIATION, Vol. 28, No. 2 (Feb. 1936), Johnson shows a startling number of defects found in a survey conducted by him covering swimming pools, hotels, hospitals and dairies. He lists 3,025 defects in 4 hotels, 1,197 in 4 hospitals, 210 in 6 dairies and 187 in 29 swimming pools.

Other surveys have been made, and in practically every case similar results are reported.

As a result of his survey, Mr. Johnson makes the following interesting statement:

"Irrespective of the past or future jurisdiction of plumbing ordinances, this condition constitutes such a distinct and dangerous hazard to public health that its control necessarily becomes a subject of grave importance to health departments, as well as water departments, and a responsibility which they cannot escape or delegate."

It would be interesting if the author would tell us what local department is held responsible for the enforcement of these rules. I note that the inspections mentioned were made by local health inspectors. Has the water department or private water company any responsibility to see that safe water is distributed from the faucet or does this responsibility end at the street line, the meter or the water main?

In the Massachusetts rules pertaining to cross connections previously mentioned is the following clause:

"No officer, board, corporation or other person or group of persons owning or having the management or control of any water supply, the water of which is furnished to any municipality or district for drinking and/or domestic and/or culinary purposes shall supply water to any person, firm or corporation maintaining such a connection".

This seems to put the responsibility squarely up to the water departments and companies to see that the regulations are lived up to before water can be supplied, even though some other department may be given jurisdiction by local ordinances.

The discussion of this subject is particularly timely now, and it should be carefully considered when this Association votes on the report of the Committee appointed to consider this subject. The report was published in the December 1937 number of this JOURNAL, and I understand will come up for action during the September, 1938, convention. I hope all our members will make it a point to read that report, study the question from all angles and be prepared to discuss and vote intelligently when this report is presented for action.

President Scott.* If I may take the liberty, I would like to comment on the question that Mr. Taylor asked about the division of responsibility, in our Connecticut cities and towns particularly, as related to the Connecticut regulations.

Our legislature in 1937 passed a law that provided that after January 1, 1938, no drainage or toilet systems should be installed except in accordance with sanitary code regulations established by the State Department of Health. The question that came up was whether the department should establish a detailed plumbing code such as has been enacted in Wisconsin, Illinois, and some other states, or whether the Department should enact more or less general regulations. The

*Connecticut State Department of Health.

Department was given no power to enforce any State plumbing code. We already had numerous plumbing codes in the State, and the Public Health Council finally decided that we could enact what are more or less in the nature of guiding regulations, that would cover the whole subject and yet not set up detailed figures,—for example, the requirement that the water supply pipe shall be of adequate size without specifying whether the pipe shall be an inch in size or three-quarters of an inch. The result is going to be, we hope, that in our cities and towns that do not have plumbing codes there will be developed enough interest so that they will either individually provide for local plumbing inspection, or where there are several small towns, perhaps too small to administer individual plumbing codes, they can get together and appoint one plumbing inspector to serve a district. The plumbers in the state are very much interested in this legislation, and they are starting to push it.

As to Mr. Taylor's question whether or not the responsibility is placed with the health department or the water department or water company, we have no specific delegation of authority now. The reason why we have asked the local health departments to assist us in this drinking-water survey is that they have the entrée to all the public buildings. We were pretty closely in touch with the health departments in the various large cities, and we felt that they could undertake this work very satisfactorily; in fact in one particular city we discussed at some length with the water department which of the two departments should undertake the survey, and they thought that the health department should do it.

Another complication that we have in Connecticut, which is not very much of a complication in Massachusetts, is that we have a tremendous number of private water companies—in fact, about 80% of our supplies numerically are privately owned—and it would seem that this is somewhat of a municipal health responsibility.

I think that the scheme which Mr. Taylor has worked out in New Bedford is excellent, and probably is the best type of attack that can be devised, because certainly the water department or water company should know more about water piping and back siphonage than the health department. We have tried to guide the local inspector in the manner of making inspections, and we also have offered to go back in questionable cases and check over conditions with him. The author has called attention, in his paper, to the desirability of the water company or the water department trying to get some local agency—whether it is the health department or the health officer, or the water company or water department—interested in making these surveys.

The author's figures have shown that these dangers are not fantastic. However, I think there has been somewhat of a tendency on the part of some plumbers to exaggerate some of the dangers, even though there are a lot of very real hazards. We went particularly after the water storage tanks, because that seemed to be the greatest hazard that we could locate in our various cities and towns where a large amount of tank water was being stored under conditions that made the water very easily subject to contamination.

Francis H. Kingsbury.* Mr. Taylor made reference to our rules and regulations as adopted on February 9, 1937. In Massachusetts the Department of Health was established many years ago purely and simply as an advisory body, on the recommendation of many of the leading members of the medical fraternity, recognizing the history of events and the desire of local communities to run their own affairs, but also recognizing that local communities might on occasion need advice, as we all do. Accordingly, very few mandatory powers have been given to the Massachusetts Department of Health. In many of the states where the health law is of more recent date, mandatory powers have been granted from the beginning. In Connecticut the State Board of Health has its Sanitary Code. If I understand the law correctly, it permits them to make definite regulations from time to time, and in the current legislature they have apparently been given additional powers.

The problem of cross-connections and the problem of the hazards to the quality of the water by pollution through plumbing cross-connections with fire-service or industrial supplies have, in our minds, been divided into two groupings. One of them, the major one, which affects the public water supply to the greatest extent as against the conditions in any one particular building, is the fire-service and industrial supply. Without attempting to get any additional legislation, we were advised by the Attorney General that under our old law, whereby we adopted rules and regulations for the protection of water sheds, we could also adopt rules and regulations to protect the water supply in the streets from pollution through fire-service or industrial supplies. Therefore we established, last year in February, those rules and regulations to which Mr. Taylor has referred, and we have made investigations along those lines and will soon inaugurate a system of inspections, which depends for its efficiency upon the coöperation of all the water works superintendents.

Now, in regard to the other phase of the matter, the conditions

*Massachusetts State Department of Health.

within the buildings—particularly the small cross-connections, and the plumbing cross-connections, so called—it is doubtful if we have any law that would permit the State Department of Health to go directly into that matter and make orders.

I might say that prior to the adoption of these rules and regulations on fire-service and industrial-supply cross-connections, we had recommended to all of the local boards of health in the State that they adopt a certain Rule 18 as a part of their plumbing rules and regulations. Rule 18 deals with the question of cross-connections in general but particularly in regard to cross-connections and plumbing in buildings.

The Legislature of Massachusetts has always been reluctant to add to the mandatory powers of our department, and this may be the wisest course. We certainly have found, and certainly believe that the enforcement of any rules and regulations, the discovering of these cross-connections and their remedies, and the continual housekeeping job, as you might term it, of supervising any new ones and getting rid of those that are put in by plumbers, by master mechanics, or others, who do not appreciate this danger, is essentially a home-rule proposition. If the paternalism of the state takes away from the responsibility of the local official his sense of duty may be impaired. It may be that in the long run our legislature is wise in not permitting us to go forward in mandatory ways. But then again that is open to argument. I think, however, that in the trend of events we may arrive at a point where we will be given mandatory powers in regard to inside-plumbing cross-connections as well as industrial cross-connections.

E. Sherman Chase.* What has been the experience in Connecticut as to actual contamination through interconnections? We have evidence of contamination, pollution and infection, through cross-connections with fire supplies and industrial supplies, but evidence in respect to contamination and infection through interconnections is rather meagre so far as published data are concerned.

President Scott. One of the things that brought the building water survey was a visit we made to a factory where we obtained a poor bacteriological analysis of the water. We found a drinking-water tank in the basement, with ammonia coils in it, the water being circulated throughout the building. We found two or three pipes—they were not sewer pipes—running on the ceiling above the tank, dripping moisture into the tank, with the tank full of dust and dirt. When we asked the superintendent of the factory if the tank was not flooded by the river when we had the large floods a couple of years ago, he said, "Yes." I

*Of Metcalf and Eddy, Boston, Mass.

said, "What did you do?" He said, "We put some soda ash in the tank." So that shows how little thought many people give to the dangers.

One most interesting thing about the survey as the author has stated is that after he had been going to several cities and had been going back for reinspections, he had never undertaken any work where the conditions were remedied so quickly. In other words, when the managements of the factories saw these conditions they were as anxious as anybody else to have them eliminated. It was just a case of calling their attention to them.

Arthur L. Shaw.* The author has called attention to the protection of submerged inlets in tanks by vacuum breakers when it is necessary to have submerged inlets. We all know of the care that has been exercised in the design and arrangement of specially constructed double check valves for the protection of the interconnections between potable and nonpotable water supplies. In the case of vacuum breakers, is it possible that they may be just as fallible as check valves, and shouldn't they be investigated and perhaps standardized with care equal to that which has been devoted to the check valve problem?

President Scott. I think you are probably right in many instances. Looking at it from one angle, the pressures are usually considerably different. In the average inlet that we have encountered in many of our factories, we almost have to have a vacuum in the water line to suck water out of some of the tanks that we have visited. We also have been advised that in some manufacturing processes it is very difficult to eliminate submerged inlets.

As to an acceptable type of vacuum breaker, the Wisconsin State Board of Health has approved one or two vacuum breakers that stood up very well in their tests. There is now on foot a movement, which is being started by the National Association of Master Plumbers, that would provide an advisory council, consisting of twelve men, two from the Eastern master plumbers, two from the Western master plumbers, two from the American Water Works Association, two from the New England Water Works Association, two from the American Public Health Association, and two from the American Medical Association, making four plumbing representatives, four water works representatives, and four health representatives on the council. The plumbers propose to incorporate a nonprofit corporation, which would employ a coördinator, who has already been selected, and also finance

*Of Metcalf and Eddy, Boston, Mass.

a testing laboratory, which is to be conducted by Professor Dawson, who was at the University of Wisconsin and is now at the University of Iowa. The thought is that different types of vacuum breakers, flushometer valves, and other apparatus that protects against back siphonage, might be officially approved through the use of this testing laboratory and the advisory council. The manufacturer would then be in a position to advertise that his particular piece of equipment had been approved by this group. The officers of the New England Water Works Association have been approached about participating. We have not taken any formal action as yet, and I don't know whether any of the other associations have.

I think personally that it would be advisable not to depend on vacuum breakers, but in actual practice, with flushometer valves, submerged inlets in dish-washing equipment, and submerged inlets in numerous other instances, the question comes up particularly in the case of the existing installations, whether we may not have to permit vacuum breakers in some instances.

Mr. Sherman. In the greatest number of cases where we found submerged inlets in tanks, it was possible to provide a vacuum breaker consisting of a funnel at a sufficient elevation above the tank to still give the desired agitation in the bottom. In many other cases they did not feel it was absolutely necessary to have the water agitated at the bottom. In most cases it was possible to eliminate those without resorting to any mechanical vacuum breakers.

ECONOMIC DESIGN OF HYDRAULIC-FILL DAM SECTIONS

BY HARRY H. HATCH*

[*Received February 1, 1938.*]

The subject matter of this paper will be confined to the economic section design of hydraulic-fill dams without going into the problems of foundation, freeboard, wave-action, slope and toe protections, spillway, etc. Each of these factors, entering into the general design of a hydraulic-fill dam, is a problem by itself requiring more or less attention; and each will have to be dealt with independently with reference to local conditions and requirements for the individual structure.

Soil or earth is the oldest material of construction known to mankind. It is undoubtedly among the very first materials used in civil engineering, beginning with irrigation ditches and dikes in ancient times. In spite of the fact that soil has been used in construction for so many centuries, there has been comparatively little study up to recently on its behavior and characteristics from a construction point of view. Not many years ago, the French engineers had a rule of thumb that no earth dam should be any higher than 20 m. (about 66 ft.). It seemed as if the function of soil as construction material, after a great many centuries of constant use, was to end in a maximum height of a 20-m. structure. Today there are successful earth dams greater than four times the 20-m. height limit set not very long ago, when the present development in the art and science of earth dam construction was unknown. There seems to be no reason for any such limits, as more and more knowledge is gained on the characteristics of soils.

The difficulty in dealing with soils is in the diversity of its physical, chemical, mineralogical, etc. characteristics. Soil is not uniform. Therefore, it is necessary to obtain full information on every phase of different soils, and with this knowledge only can an engineer of experience attack the problem in each case for that particular locality. Notwithstanding the tremendous difference in the characteristics of the soil, it is possible to express in simple mathematics the fundamental principles of the design and the relations or the relative importance of the various factors affecting the design of a hydraulic-fill dam. After all, irrespective of location, the engineering purpose of

*Division Engineer, Springfield Water Works, Springfield, Mass.

a hydraulic-fill dam and the function of its core and shoulders are the same.

Had the unit values of a hydraulic-fill dam material, such as specific gravity, percentage of voids, weight, coefficient of friction, etc., been constant, more or less similar to concrete, there is no reason why there could not be a standard profile or section for hydraulic-fill dams; but due to the variation in the characteristics of materials found at various locations, practically each structure has to be considered by itself, and the general design has to be modified or adjusted to the characteristics of the local material. It is taken for granted that the material on hand is suitable or adaptable for hydraulic-fill dam construction.

It is a known fact that the greatest danger to hydraulic-fill dams is during their construction, and not after their completion. Economic safety against the greatest danger, therefore, requires that the design and construction of both shoulders should be alike or symmetric. Most of the hydraulic-fill dams constructed lack this symmetry. The two shoulders as a rule have different volume, different dimensions, different outside and inside slopes, etc. Mathematically, one wonders why. Is it due to lack of a true concept of the economic design or are there real reasons for this departure from the apparent engineering economy? The intention here is not to call attention to the difference in riprap or slope protection on account of ice, wave action, drawdown, washouts, and piping or toe protection, etc., but to the important difference in the factors of safety of the two shoulders of the same dam, which really means difference in volume, hence more construction cost.

A study of the dimensions and slopes of various hydraulic-fill dams in existence will show that apparently there is no consistency whatever in their design. In some cases the slopes of both shoulders are the same; in many of them the upstream shoulder slope is flatter than that of the downstream; and there are dams with downstream shoulder slopes flatter than those of the upstream. Almost similar inconsistency exists in the core slopes of these dams. It might be readily understood why one dam should have flatter slopes than another, but there seems to be no plausible explanation for such apparent contradictory designs in these dams. Can this be due to the lack of knowledge of the true principles of the design for hydraulic-fill dams, or is it due to difference of the characteristics of the construction material? This will be revealed when the local requirements of the design and the characteristics of the local material are known, and applied to the general design equations.

In the derivation of the formulas presented in this paper, it is assumed that the shoulders will fail along a horizontal plane. This assumption is near enough for practical purposes, and it will simplify the equations.

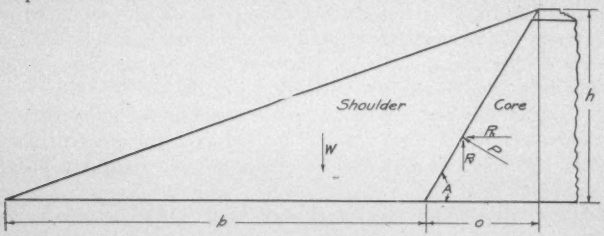


Figure 1

In Figure 1, let:

w = Weight of core material per cubic foot.
w′ = Weight of shoulder material per cubic foot.
W = Total weight of shoulder material.
h = Height of dam.
C = Coefficient of Friction of shoulder material.
F = Factor of safety.
A = Angle of the core slope with horizontal.
P = Total core pressure for height h.
P_h = Horizontal component of P.
P_v = Vertical component of P.
S = Outer slope of the shoulder, horizontal to vertical.

Then:

(1) $P = \frac{1}{2}wh^2$

(2) $P_h = \frac{1}{2}wh^2\sin A$

(3) $P_v = \frac{1}{2}wh^2\cos A$

(4) $W = \frac{1}{2}w'bh$

(5) $F = \dfrac{C(W-P_v)}{P_h}$

(6) $F = \dfrac{b}{h}\dfrac{w'}{w}\dfrac{C}{\sin A + C\cos A}$ from equations (1) to (5) inclusive.

(7) $b = \dfrac{w}{w'}Fh\left(\dfrac{\sin A}{C} + \cos A\right)$ from equation (6).

(8) $o = h\cot A$ from Fig. 1.

(9) $b + o = h\left(\dfrac{w}{w'}F\left(\dfrac{\sin A}{C} + \cos A\right) + \cot A\right)$ from equations (7) and (8).

(10) $S = \dfrac{b+o}{h}$, or

(11) $S = \dfrac{w}{w'}F\left(\dfrac{\sin A}{C} + \cos A\right) + \cot A$

General equations for the factor of safety, the base and the outer slope of the shoulder are (6), (7) and (11), respectively. Their application can best be illustrated by their further simplification through substitution of numerical values, met in practice, to some of their terms.

For some glacial deposits a specific gravity of 2.7 will be assumed. A core material at 50% voids and saturated with water is considered exerting full fluid pressure with a weight of about 116 lb. per cu. ft. The shoulder material of glacial deposits at about 35% voids will weigh around 110 lb. per cu. ft. However, the presence of organic matter in the core material would tend to decrease its unit weight of 116 lb., and the presence of moisture in the shoulder material would tend to increase its unit weight of 110 lb. Thus, without any appreciable error w can be assumed equal to w'. Then from equation (6):

$$(12)\quad F = \frac{b}{h}\,\frac{C}{\sin A + C\cos A}$$

With a factor of safety of one, which means that the acting and reacting forces are just in balance, the minimum values for b and S are given by

$$(13)\quad b = h\left(\frac{\sin A}{C} + \cos A\right) \qquad \text{from equation (7).}$$

$$(14)\quad S = \frac{\sin A}{C} + \cos A + \cot A \qquad \text{from equation (11).}$$

There has been no definite or standard factor of safety in the hydraulic-fill dams constructed. The designer in each case has decided what should be the factor of safety of his structure. For given values of h, C and A, the factor of safety will vary directly as b, or as the volume of the shoulder material. It may be necessary again to call attention to the fact that the shoulder material under discussion is a suitable one, or the kind that is free from objectionable fines and will readily and entirely drain and become hard.

It is evident from equations (13) and (14), the equilibrium formulas, that the economic design depends entirely upon the values of C and angle A.

The value of C, the coefficient of friction, is the inherent characteristic of the particular shoulder material. Not only is there a large difference in its value for different hydraulic-fill dam materials, but it is not constant for the same material in various elevations of the same structure, according to experiments conducted at Cobble Mountain. The variation in the value of C is also different for different materials.

The relation between C and vertical pressure p in lb. per square inch for Cobble Mountain Dam* beach material is

$$(15) \quad C = 0.98\,p^{-0.05}$$

This relation was obtained with clean sand and gravel of beach materials from glacial deposits. It will not be applicable for other types of material, nor will it apply to the same type of material containing objectionable fines. Equations (15) to (19) are given to show the influence of the coefficient of friction on the design. The principle can be applied to other materials under consideration.

Substituting for p in equation (15) the corresponding vertical height, h, of the same type of material, the relation between coefficient of friction and the height of the dam, h, can be expressed approximately by:

$$(16) \quad C = 0.98(0.76h)^{-0.05} = 0.9935h^{-0.05}, \text{ or approximately.}$$

$$(17) \quad C = h^{-0.05}$$

Figure 2 is a graph of equation (17), giving the approximate relation between h, the height of the dam, and the coefficient of friction of its shoulder materials, consisting of clean sand and gravel from glacial deposits and weighing 110 lb. per cu. ft.

The minimum value of b for a given angle A, from equations (13) and (17) is:

$$(18) \quad b = h^{1.05}\,\sin A + h\cos A$$

The minimum value of S for a given angle A, from equations (14) and (17) is:

$$(19) \quad S = h^{0.05}\,\sin A + \cos A + \cot A$$

Figure 3 is a plot of equation (19), or of the required minimum section profiles for various core slopes, with their angles varying from 36°—52′ to 84°—17′. These core slopes are taken from actual hydraulic-fill dams. The decrease in the value of C, as the height of the dam increases, indicates that for economic design the shoulder slope should be concave and not a straight line. The required shoulder slope curvature for Cobble Mountain Dam material is very flat. However, this concave slope requirement will be more pronounced for construction materials having greater variation in their coefficient of friction values because of increasing height in the structure. The equation for economic design calls for a continuous slope, and therefore berms are

*Figure 10, Page 228, Transactions American Society of Civil Engineers, 1934.

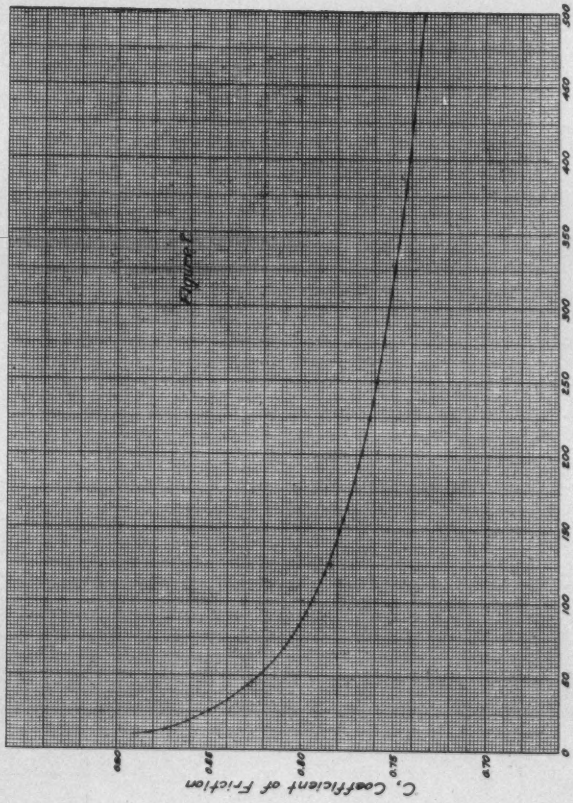


Figure 2
h, Height of Dam in Feet
0
50
100
150
200
250
300
350
400
450
500
C, Coefficient of Friction
0.60
0.65
0.70
0.75
0.80

FIGURE 2

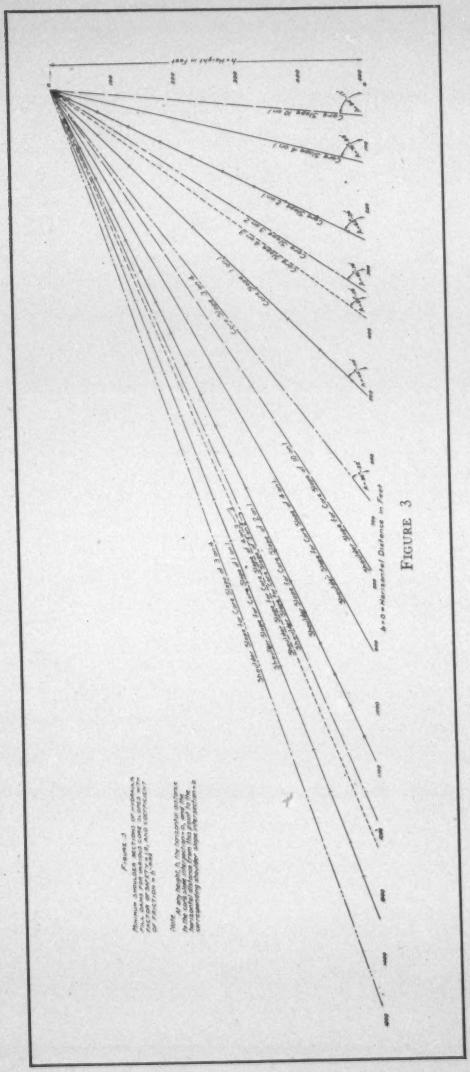


FIGURE 3

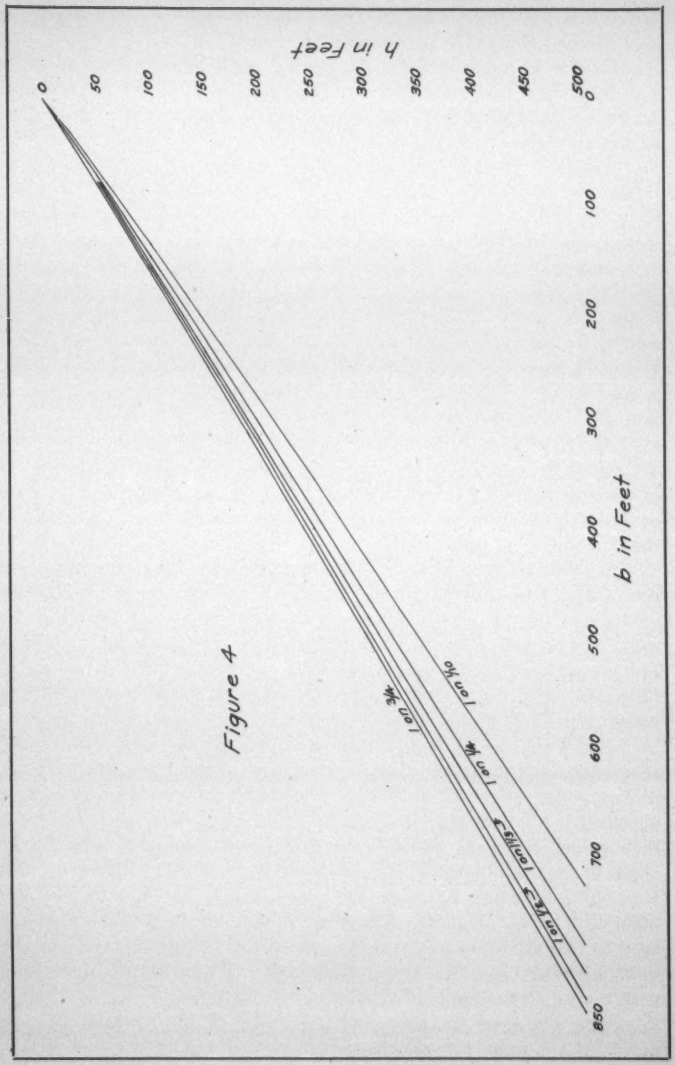

h in Feet
0
50
100
150
200
250
300
350
400
450
500
0
100
200
300
400
500
600
700
850
b in Feet
1on ½%
1on ¾%
1on 1%
1on 1½%
1on 2%
1on 3%

Figure 4

not economical unless the purpose they are to serve will offset the cost of the extra material necessary for them.

The wide range of the distances out to the shoulder slopes along any horizontal plane for corresponding height, h, is not entirely due to the effect of the core slope, but mainly to the horizontal projection of the core slope within the core limits.

Figure 4 gives the values of b for corresponding values of h in equation (18) for the identical core slopes given in Figure 3. Figure 4, in fact, gives the required minimum shoulder areas for various core slopes, the material being similar to that of Cobble Mountain Dam. It is interesting to note that the minimum shoulder material required for a core slope of 1 on ⅔ (3 on 2) is practically the same as that for a core slope of 1 on ¾ (4 on 3); the minimum shoulder material required for core slopes of 1 on 1 and 1 on ½ (2 on 1) are also alike. It is seen that in Figure 4 with h equal to 300 ft., the required minimum b is 427 ft. for the steepest core slope of 1 on 1/10 (10 on 1) and 479 ft. for the flattest core slope of 1 on 1⅓ (3 on 4); yet for core slopes of 1 on ¾ and 1 on ⅔ the required minimum values of b, according to equation (18), are 499.2 and 498.4 ft., respectively. It is evident that, within the range of the given core slopes in Figures 3 and 4, the value of b does not necessarily decrease continuously as the core slope becomes steeper.

It will be on the safe side to make the design by applying throughout the whole structure the minimum value of the coefficient of friction at the maximum height of the dam, when the shoulder slope will become a straight line rather than concave. During the last few years, large massive rock toes have become typical for hydraulic-fill dams. These rock toes will tend to shorten the base, thus getting away from the concave shoulder slopes through their depth.

Figure 5 is a plot of equation (14) for various values of C. The required minimum shoulder slope for a given core slope can be readily picked under different values of C. It should be remembered that S, obtained in the equilibrium formula, for a steep core slope and for a high value of C may not be a workable slope in practice due to the angle of repose of that particular shoulder material. However, this investigation should be made after applying to the equilibrium formula the factor of safety for construction. It might be necessary here to call attention to the difference in the factors of safety of the same hydraulic-fill dam during and after its construction, especially with the rapidly consolidating type of core material.

Figure 6 gives the values of b/h, ratio of the shoulder base to height of the dam, for various values of C, for different core slopes.

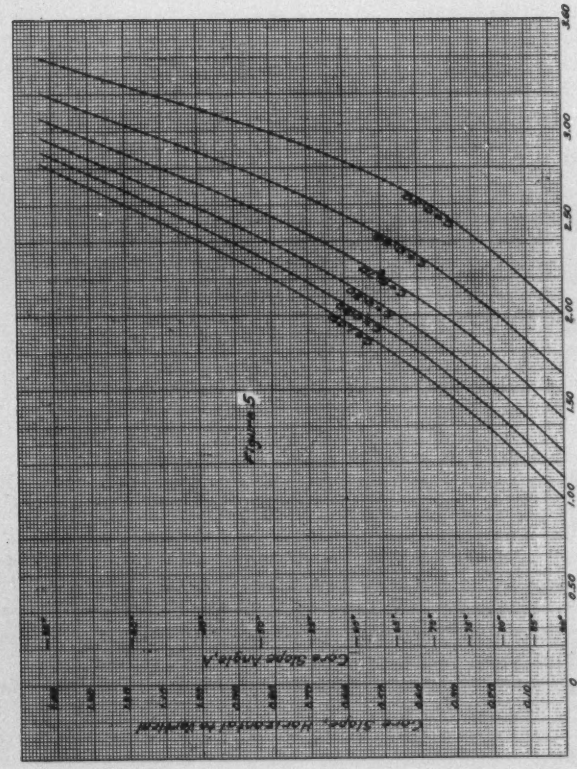


Figure 5
Core Slope, Horizontal to Vertical
Core Slope Angle, A
S = Slope of Shoulder, Horizontal to Vertical
0
0.50
1.00
1.50
2.00
2.50
3.00
3.50

FIGURE 5

In Figure 6 can be seen a critical or a maximum point for b/h under each value of C. Thus, for a given C, there is a core slope that would be the least economic, and beginning with it the minimum requirements for b will be less and less both by the decrease and the increase of the core slopes, within working ranges.

The critical point on each curve in Figure 6 can be determined by setting the first derivative of equation (13) equal to zero and solving the resulting equation:

(20) $\text{Cos}A = \text{Csin}A$, or $C = \cot A$

It will be found that the least economic core slope angles for various values of C are as follows:

C	*Angle A*
1.0	45°—00′
0.9	48°—01′
0.8	51°—20′
0.7	55°—00′
0.6	59°—02′
0.5	63°—26′

The importance of the core slope on the economic design of hydraulic-fill dam can be appreciated from equation (13) and Figure 6. The designer, however, in deciding upon the core slope also has to take into consideration other factors, such as, the character of the available borrow material; the freeboard; the width at the top of the dam; feasibility of wasting excess fines, if any; the desired degree of watertightness in the structure, or the necessary percentage of the core width to the entire base at any elevation; and whether rapidly or slowly consolidating type of core, etc.

In the application of the equilibrium formula given in these pages to any proposed or actual dam, it should be remembered that they were obtained for a factor of safety of one and with certain values of C, w and w′, which may be different for the structure under consideration.

The character of the core material is of utmost importance. The economic design and construction of the dam will be affected by its core material, whether of rapidly or of slowly consolidating type. By rapidly consolidating type of core is meant the kind of core material that will attain final or nearly final consolidation at the end of its construction or before the structure is put to use. By slowly consolidating type of core is meant the kind of core that will attain final consolidation in longer periods, up to 100 years or more.

When the core material is consolidated it becomes an integral part of the dam and, therefore, provides additional safety to it. This is the reason for the difference between factors of safety of a dam during and after construction.

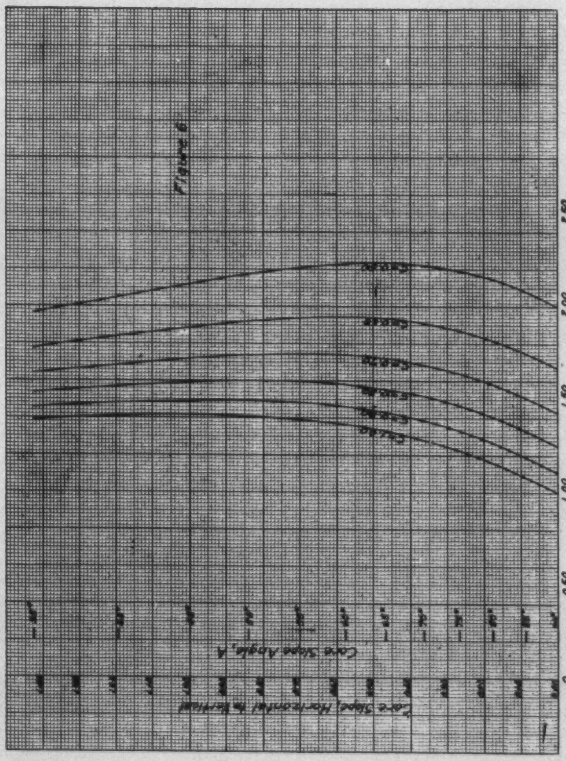


Figure 6
Core Slope Horizontal to Vertical
Core Slope Angle, A
0
0.50
1.00
1.50
2.00
2.50
$\frac{b}{h}$, Ratio of Shoulder Base to Height

FIGURE 6

If the core material is of the rapidly consolidating type, its consolidation will increase the factor of safety of the dam even during its construction. High hydraulic-fill dams usually take 2 or 3 seasons to be built, and the rapidly consolidating core material in the lower sections, long before completion of the job, will cease being a liability and instead contribute additional safety. If desired, this benefit can be used to advantage by reduction of the shoulder width in the lower elevations of a high structure, or perhaps by allotting a smaller factor of safety to the lower sections of the dam than higher up.

No matter how long, ultimately final consolidation, hence final settlement, will take place in a slowly consolidating type of core. This will be gradual, but certain.

Every core material has a definite percentage of voids at its final consolidation under a given load. This is not uniform throughout the depth of the core. Therefore at the bottom of the dam the percentage of voids of the core material will be the least and will gradually increase to the top. The difference in average percentage of voids at the end of construction and at ultimate consolidation will vary greatly for core materials. However, as an illustration, for this type of core material it will be assumed that the average percentage of voids of the core at the completion of the job is 52 and that at ultimate consolidation it is 42, or an average reduction of 10% in the voids of the core material. The author believes that this 10% reduction is conservative and that in many cases the range may be more.

Shrinkage of volume of core material due to reduction in its percentage of voids is expressed by the equation:

$$(21) \quad R = 100 \frac{V - V'}{100 - V'},$$

where R is the percentage shrinkage, V, the original percentage of voids, and V' the final percentage of voids.

According to equation (21), there will be 17.2% shrinkage in the volume of the core because of a change of its percentage of voids from 52 to 42; 16.7% for a change from 50% to 40% voids; and 16% for a change from 47½% to 37½% voids.

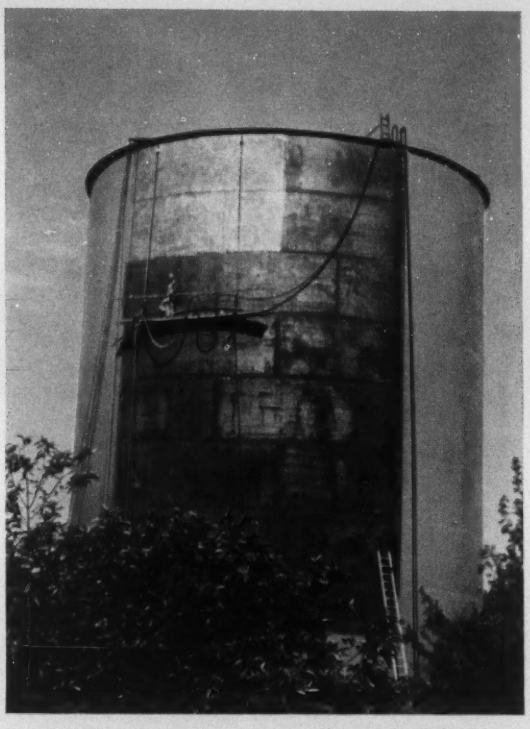
In an actual high hydraulic-fill dam with about 300,000 cu. yd. of core material, with a slowly consolidating type of core, a conservative shrinkage of 16% would mean 48,000 cu. yd. of water paid for as material. Ultimately this amount of water from the core will disappear and there will be a settlement in the dam equal in yardage. The resulting settlement will not be equal all along the longitudinal axis on top of the dam, but maximum in the center and gradually

decreasing to zero at each abutment. The outline of the dam will not be that contracted and paid for. The particular dam was designed for a rapidly consolidating type of core material. In the investigation as to what would happen if the core material would have been that of a slowly consolidating type, it was discovered that the designed freeboard would practically have disappeared when ultimate consolidation took place. Thus there would be danger of overtopping and washout, and periodic repairs and additional material would be necessary to maintain the highway across its top. On account of uneven longitudinal settlement on top of a high dam with slowly consolidating type of core, it is easy to visualize what will happen to masonry walls and concrete superstructures, if any. In some cases, there are conduits through hydraulic-fill dams. Unless they are safeguarded against this uneven settlement, the result will be far from desirable.

There cannot be any question about the preference for a rapidly consolidating type of core from strength and economy viewpoints, especially when the available borrow material will provide the choice, or when local requirements and conditions make it feasible.

The engineer in charge of construction should have a thorough knowledge of the principles of hydraulic-fill dam design and the functions of the constituent parts of the dam being constructed. Design and construction should agree. The benefit of an economic design will depend much on whether the constructed dam meets the designer's specifications. Of what value can be the economic core width, core angle, etc., if the constructed core and its slope angle are entirely different from the design requirements?

The author is indebted to E. E. Lochridge, Chief Engineer of the Board of Water Commissioners, Springfield, Mass., for his useful suggestions and criticism, and to R. P. Moxom, Jr., Assistant Engineer, Springfield Water Works, for assisting in the computations and in preparing the drawings.



Photograph by W. J. Lumbert

The first and largest all butt-welded
Standpipe in New England

SANDBLASTED AND PAINTED

by

J. H. TREDENNICK, INC.

10 HIGH STREET
BOSTON, MASS.
Telephones: Liberty 2480—Parkway 0285

STANDPIPE PAINTING

The problem of painting your standpipe, in all probability, does not involve the costly treatment pictured on the preceding page. This procedure is recommended only for new standpipes, standpipes previously painted over mill scale, and those not painted for so long that they are badly pitted.

The ordinary repaint job requires good paint, a thorough cleaning job, and experienced and trained artesans. The leading paint manufacturers have spent years in experimentation and millions of dollars in developing paints to meet your requirements. J. H. TREDENNICK, INC., has spent over thirty years in developing the most up-to-date cleaning methods and training men in the best painting technique. Our power wire brushing system is known throughout New England, and we suggest that you seek your paint supplier's opinion regarding the advisability, the economy, and even the necessity of our thorough cleaning methods.

We have successfully completed the painting of the following standpipes, during the past two seasons:

Westerly
East Providence
North Attleboro
Hanover
Scituate
Marshfield
Quincy
Marblehead
Brookfield
Winthrop
Reading

We number among our customers such consumers as:

American Oil Company
Gulf Oil Corporation
Atlantic Refining Company
New England Power Company
Stone & Webster, Incorporated
General Electric Company

Should you wish to discuss the maintenance of your standpipe, call or write

J. H. TREDENNICK, INC.

10 HIGH STREET

BOSTON, MASS.

Telephones: Liberty 2480 Parkway 0285

INDEX OF ADVERTISERS

	Page
Atlas Mineral Products Co.	xxv
Bailey, Howard E.	iii
Barbour, Frank A.	ii
Barrows, H. K.	ii
Bingham & Taylor	iv
Brainard, F. S. & Co.	xxv
Caldwell, Geo. A., Co.	xiii
Cement Lined Pipe Co.	xxv
Crosby, Irving B.	iii
Darling Valve & Mfg. Co.	ix
Donaldson Iron Co.	xxiv
Dresser, S. R., Mfg. Co.	Following front cover
Eddy Valve Co.	xv
Edson Corp., The	xxii
Ellsworth, Samuel M.	ii
Everett, Chester M.	ii
Fairbanks-Morse Co.	xxiv
Farnan Brass Works Co.	xxxiii
Fay, Spofford & Thorndike	ii
Ford Meter Box Co.	xvii
Goodnough, X. Henry, Inc.	ii
Hayes Pump and Machinery Co.	xvii
Hays Mfg. Co.	xviii
Hersey Mfg. Co.	v
Hydraulic Development Corp.	x
Industrial Chemical Sales Division—West Virginia Pulp and Paper Co.	xix
Johns-Manville	xi
Kennedy Valve Mfg. Co.	xiv
Layne-Bowler New England Co.	iii
Leadite Co.	Back cover
Lock Joint Pipe Co.	Facing front cover
Ludlow Valve Mfg. Co.	xvii
Metcalf & Eddy	ii
Mueller Co.	xxxi
National-Boston Lead Co.	xvi
National Gunite Contracting Co.	iii
National Meter Co.	xii
National Water Main Cleaning Co.	viii
Neptune Meter Co.	vi
New England Water Works Association	viii
Pirnie, Malcolm	ii
Pierce-Perry Co.	xxv
Pitometer Company	ii
Pittsburg Equitable Meter Co.	Following front cover
Red Hed Mfg. Co.	xxxii
Rensselaer Valve Co.	xxiii
Reppucci, C. & Sons, Inc.	iii
Ross, Anthony & Son, Inc.	iii
Ross Valve Mfg. Co.	viii
Smith, The A. P., Mfg. Co.	xvii
Thorpe, Lewis D.	ii
Tredennick, J. H., Inc.	Preceding index of advertisers
Turbine Equipment Co.	xx
U. S. Pipe and Foundry Co.	Facing back cover
Wailes Dove-Hermiston Corp.	xxiii
Wallace & Tiernan	xxi
Warren Foundry and Pipe Corp.	xxii
Weston & Sampson	iii
Whitman & Howard	iii
Wood, R. D., Co.	xxvi
Worthington Pump and Machinery Corp.	vii

(Classified index on page xxvii)

ENGINEERS

FRANK A. BARBOUR
Consulting Engineer

Water Supply, Water Purification, Sewer and Sewage Disposal, Valuations

Tremont Building, Boston, Mass.

H. K. BARROWS
M. Am. Soc. C. E.
Consulting Hydraulic Engineer

Water Power, Water Supply, Sewerage, Drainage, Investigations, Reports, Valuations, Designs, Supervision of Construction

BOSTON, MASS. 6 BEACON ST.

Samuel M. Ellsworth
M. Am. Soc. C. E.
Consulting Engineer
Water Supply and Sewerage
Investigations, Reports and Designs, Supervision of Construction and Operation
12 Pearl Street, Boston

FAY, SPOFFORD & THORNDIKE
ENGINEERS
Frederic H. Fay — Charles M. Spofford
John Ayer — Bion A. Bowman
Carroll A. Farwell — Ralph W. Horne
Water Supply—Sewerage—Drainage
Structural and Foundation Problems
Investigations Reports Designs Valuations Engineering Supervision
11 BEACON STREET BOSTON

THE PITOMETER COMPANY
ENGINEERS
Water Waste Surveys
Trunk Main Surveys
Water Distribution Studies
Penstock Gaugings
50 Church Street New York City

CHESTER M. EVERETT
Successor to
FULLER & EVERETT HAZEN & EVERETT
Consulting Hydraulic and Sanitary Engineer
Water Supply, Sewerage, Drainage, Valuations, Supervision of Construction and Operation
22 East 40th Street New York City

X. HENRY GOODNOUGH, Inc.
Engineers
BAYARD F. SNOW
Water Supply, Drainage, Sewerage, Sewage Disposal, River Improvement, Disposal of Municipal and Industrial Wastes
14 BEACON ST. BOSTON, MASS.

METCALF & EDDY
ENGINEERS
Water, Sewage, Drainage, Garbage and Industrial Wastes Problems
Laboratories Valuations
BOSTON, MASS. Statler Building
HARRISBURG, PA. Telegraph Building

MALCOLM PIRNIE
ENGINEER
Water Supply, Treatment, Sewerage Reports, Plans, Estimates, Supervision and Operation, Valuation and Rates.
25 West 43rd Street, New York, N. Y.

LEWIS D. THORPE
Civil and Sanitary Engineer
Water Works, Sewerage and Sewage Disposal
Supervision of Construction and Operation
6 Beacon Street
BOSTON, MASS.

ENGINEERS

WESTON & SAMPSON

Consulting Engineers

Robert Spurr Weston George A. Sampson

Water Supply and Sewerage
Chemical and Bacteriological Laboratory

14 BEACON ST. BOSTON, MASS.

WHITMAN & HOWARD

HARRY W. CLARK, Associate

Civil Engineers

(Est. 1869. Inc. 1924.)

Investigations, Designs, Estimates, Reports and Supervision, Valuations, etc., in all Water Works and Sewerage Problems

89 BROAD ST. BOSTON, MASS.

IRVING B. CROSBY

Consulting Engineering Geologist

Investigations of Dam and Reservoir Sites and Groundwater Supplies

6 BEACON ST. BOSTON, MASS.

HOWARD E. BAILEY

Consulting Sanitary Engineer

Water Works Water Purification
Sewerage Sewage Treatment
Industrial Wastes Disposal

117 State St., Boston, Mass.

WATER WORKS CONTRACTORS

C. REPPUCCI & SONS, INC.

GENERAL CONTRACTORS

Ground Water Supply
Gravel Packed Wells Driven Wells
Water Works Reservoirs
Drainage and Sewerage Works

10 Garden Court Street (Tel. Lafayette 7330) Boston, Mass.

ANTHONY ROSS & SON, INC.

Public Works Contractors
(Since 1890)

Water Works, Sewerage and Sewage Disposal

Office and Yard
173 Bedford Street, Lexington, Mass.
Tel. Lex. 1032

Layne-Bowler New England Company, Inc.

Developers of High Capacity Patented Gravel Wall Wells

P. D. BOWLER, Pres.

Statler Building Boston — Telephone Liberty 5795

WATER WORKS CONTRACTORS AND SUPPLY HOUSES

Your card may be inserted in this space for $12 per year

RESERVOIRS and TANKS LINED and RESTORED

with

GUNITE

NATIONAL GUNITE CONTRACTING COMPANY

Engineers and Contractors

82 W. Dedham St. BOSTON

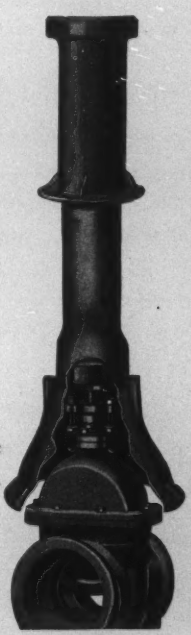
BINGHAM & TAYLOR'S Sliding Type Service and Valve Boxes are meeting with the approval of many New England Waterworks officials.

The cuts shown are our two and three piece sliding type adjustable valve boxes.

The flange on the bottom of the top section can be located any distance from the top.

We carry a complete stock on hand at all times.

Wire, phone or write us when you are in a hurry for a shipment.

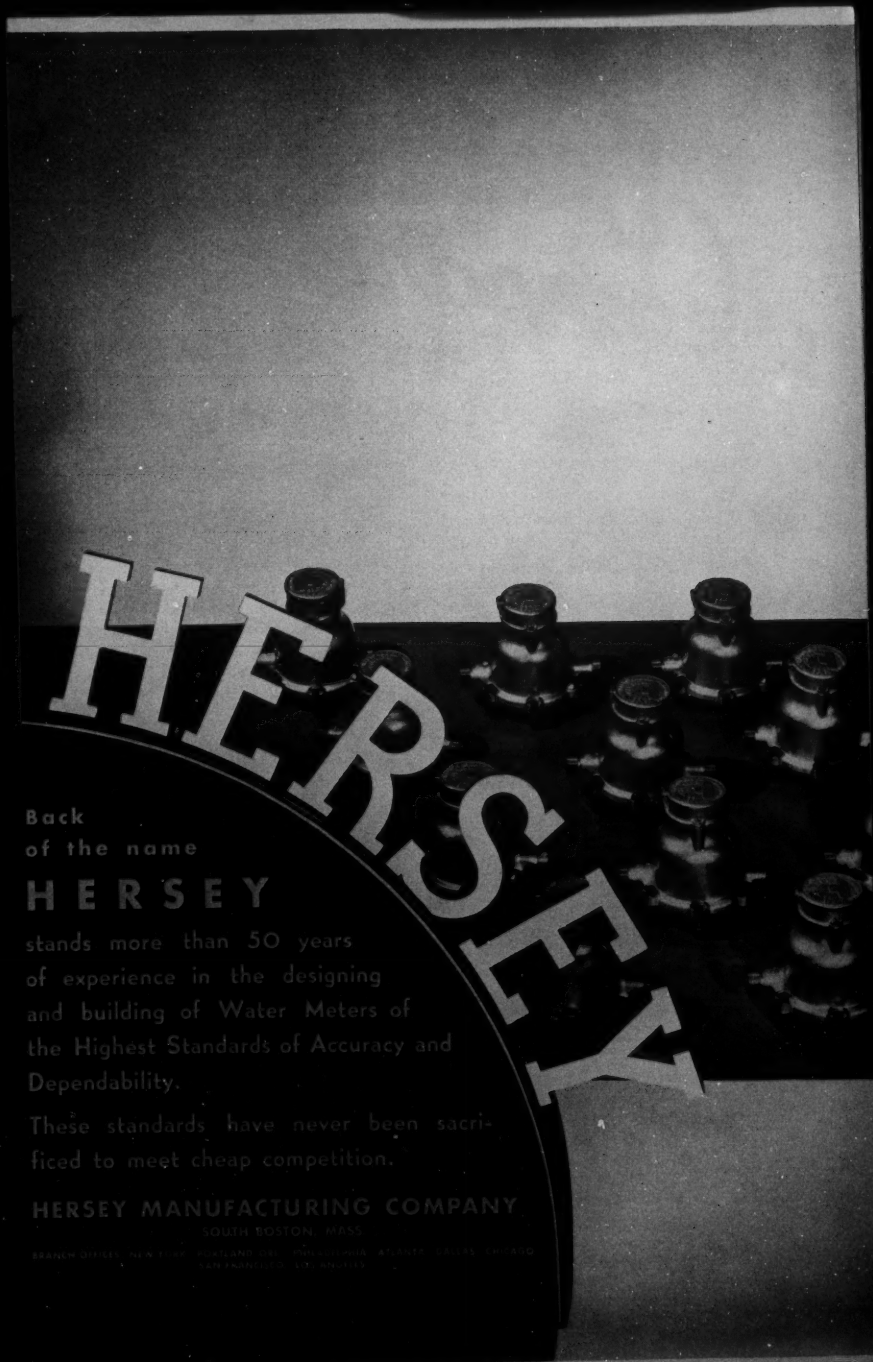


ESTABLISHED 1849

Bingham and Taylor Corporation

MANUFACTURERS

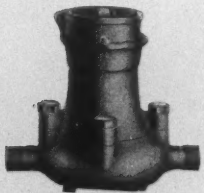
575-601 Howard Street - - Buffalo, N. Y.


HERSEY
Back
of the name
HERSEY
stands more than 50 years
of experience in the designing
and building of Water Meters of
the Highest Standards of Accuracy and
Dependability.
These standards have never been sacri-
ficed to meet cheap competition.
HERSEY MANUFACTURING COMPANY
SOUTH BOSTON, MASS.

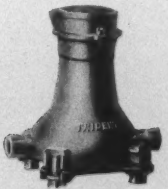
Compare THESE STANDARDS OF ACCURACY

The American and New England Water Works Associations' Standard Specifications for ⅝" cold water meters allow a range of 4% in accuracy within "normal test flow limits," these test flows being from a minimum of one gallon to a maximum of twenty gallons a minute. The "minimum test flow" of ¼ gallon a minute demands an accuracy of 90% or better.

The Neptune Meter Company's Standard Specifications for the ⅝" standard Trident Meters allow a range of **2.2%** in accuracy within "normal test flow limits," these test flows being from a minimum of one gallon to a maximum of twenty gallons a minute. The test flow of ¼ gallon a minute demands an accuracy of **95%** or better. **The "minimum test flow" of ⅛ gallon a minute demands an accuracy of 90% or better.**



SPLIT CASE



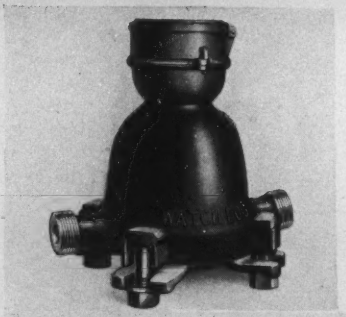
FROST PROOF

ONE RESULT OF THE PRECISION MANUFACTURE OF

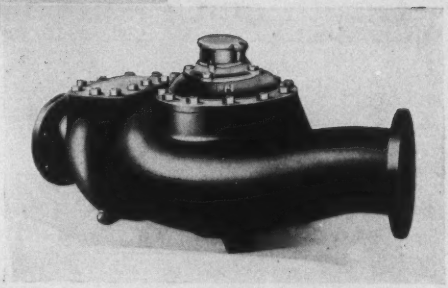
Trident WATER METERS

Neptune Meter Company, 50 West 50th St. (Rockefeller Center), New York City
Neptune Meters, Ltd., 345 Sorauren Ave., Toronto, Canada

WATCH DOG METERS



Frost-proof meter



Turbine meter

Investigate these meters

. . . more than 3,500,000 now in use

WHEN looking over your requirements, remember that thousands of municipalities are getting satisfactory low-cost service from Worthington-Gamon Meters.

WORTHINGTON-GAMON METER COMPANY

General Offices: HARRISON, NEW JERSEY

Offices and Representatives in Principal Cities

WORTHINGTON-GAMON

WGS-7

THE STANDARD FOR OVER 50 YEARS

Automatic Pressure Control Valves
Water Works Specialties

Altitude — Pressure Reducing — Surge
Relief and Combination Valves
Portable Fire Hydrants
Hydraulic Booster Pumps

ROSS VALVE MFG. CO., Inc. Troy, N.Y.

Health and Protection First

Water delivered through dirty pipes
may be a MENACE.

Incrusted water pipes mean inefficiency
and loss of Fire Protection.

We Guarantee the Results of Our
Method of Cleaning.

WRITE US.

National Water Main Cleaning Co.

50 Church Street New York City

THE NEW ENGLAND WATER WORKS ASSOCIATION

is very desirous of obtaining
the following early issues of the Journal:

Vol. 2, Nos. 1, 2, 3. Vol. 8, No. 1.
Vol. 3, No. 1. Vol. 11, No. 4.

Please communicate with the office
613 Statler Building
Boston, Mass.

QUALITY

In every industry there is some one product that by sheer merit and outstanding quality and performance is accepted as the standard by which other similar products may be judged.

Such is the Darling Gate Valve.

DARLING VALVE & MANUFACTURING COMPANY
Williamsport, Pa.

Representatives in:
New York
Houston
Philadelphia
Pittsburgh
Toledo
Oklahoma City
Evanston, Ill.

DARLING GATE VALVES

"Never a Failure in Over 22 Years!"

WE like to talk about saving in material and labor—the strong, tight, flexible joints made with Hydro-Tite—the thousands of miles of pipe jointed with it.

More important, perhaps, is the fact that with hundreds of users—each laying pipe under different conditions—not a single one has reported a Hydro-Tite failure.

We make it very easy for you to change over to Hydro-Tite. Our Data Book outlines a novel proposition. Write for it.

A Symbol of Quality

A Dependable Self-Caulking Joint Compound

HYDRO-TITE

HYDRAULIC DEVELOPMENT CORPORATION

Main Sales Office: 50 Church Street, New York, N. Y.
General Offices and Works: West Medford Station, Boston, Mass.

PENNSYLVANIA: Long lengths of Transite Pipe are comparatively light, easily transported to the job and rapidly handled by installation crews.

NORTH CAROLINA: Hundreds of municipalities throughout the United States are finding in Transite Pipe the answer to their water-transportation problems.

SAVINGS JUST STARTING ON THESE 3 TRANSITE JOBS

EVERY community that installs J-M Transite Pipe enjoys this 3-way saving in water transportation...

INSTALLATION is economical. The long lengths of Transite Pipe are light, transported to the job at low cost and easily handled by installation crews. Simplex Couplings speed up assembly . . . require no caulking . . . eliminate the need for large bell holes. Trenches can be held to minimum width.

MAINTENANCE is practically zero. Transite Pipe is made of two inherently permanent minerals, asbestos and cement. It has exceptional resistance to the corrosive action of acid soils and ground waters. And because it is non-metallic, it is immune to electrolysis.

PUMPING COSTS are low at the start, because J-M Transite Pipe has an unusually smooth interior surface. And it *stays* smooth. Transite, being non-metallic, *can never tuberculate*. This does away with one of the major causes of increased pumping pressures and reduced carrying capacities.

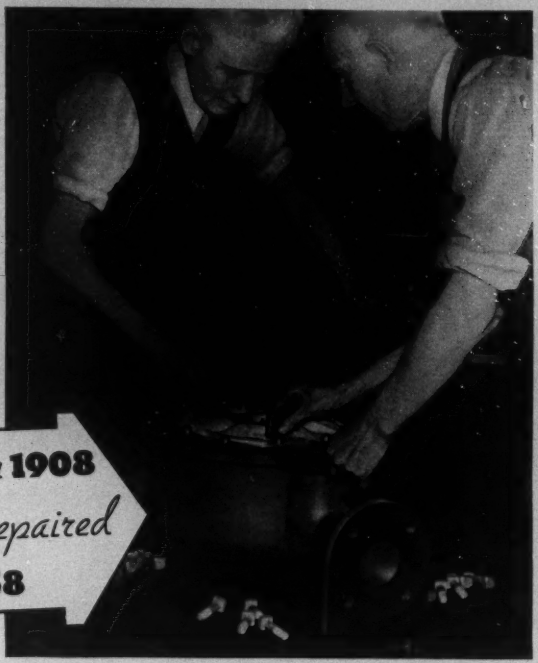
The more you know about Transite Pipe, the more clearly you will see why it assures efficient, permanently economical water-carrying systems. For the new Transite Pressure Pipe Brochure, write Johns-Manville, 22 East 40th Street, New York City.

NEVADA: Long sweeps can easily be laid with straight lengths of Transite Pipe. Simplex Joints are flexible, yet remain permanently bottle-tight.

JOHNS-MANVILLE JM PRODUCTS

Johns-Manville TRANSITE PRESSURE PIPE

AN ASBESTOS PRODUCT



and by the same men who built it!

Left, Frederick Ditchfield. Length of service, 55 years.

Center, Empire Meter Number 653058. Length of service, 30 years. Piston and intermediate replaced. Meter now ready for many years of additional service.

Right, William Giroud. Length of service, 51 years.

NATIONAL *Meters*

NATIONAL METER COMPANY, 4207 First Avenue, Brooklyn, New York

BOSTON • CHICAGO • DALLAS • LOS ANGELES • SAN FRANCISCO

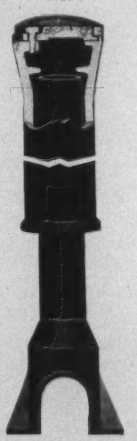
A REMINDER OF OUR
CURB-ROADWAY & VALVE BOX

SERVICE for YOU

150 Styles, Sizes and Lengths Always in Stock
90% of Orders are Shipped on Day of Receipt

This Service, the Quality and the Net Price combines to your profit and our ever-growing Box business.

No. 1



No. 10

No. 664

No. 1. An extra heavy top-sectioned service box.
No. 10. Stocked in 3 to 5 ft. sizes—for the larger gates.
No. 664. Stocked in 3 to 6 ft. sizes—for the smaller gates.
Nos. 10 & 664. Top sections can be furnished without flange or with flange at center or botton.

GEORGE A. CALDWELL CO.

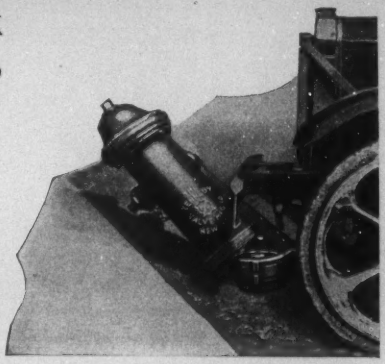
Everything For Water Service Work From Main to Meter

Phone BLUe Hills 2791

BOSTON Mattapan Square MASS.

When a truck runs "amuck"

and crashes into a Kennedy SAFETOP Fire Hydrant



Send for Bulletins

IN NO INSTANCE—either on demonstration test or in accidental collisions, has the Safety Breakable Section ever failed in its function of preventing breakage of the major and expensive parts of the SAFETOP. The only parts that need be replaced after breakage are a threaded standpipe ring and a stem coupling. These parts cost $6.00—a very small fraction of the cost of the complete hydrant which must ordinarily be replaced after breakage from accidental collision. Repairs do not necessitate shutting off the water pressure, and can be completed within half an hour.

In addition to its unique safety feature, the Kennedy SAFETOP Fire Hydrant assures quick response with full main pressure delivered at the nozzle in fire service; and its simple operating mechanism and wear-resisting valve facings last indefinitely. Write for bulletins describing its many special features.

The Kennedy Valve Mfg. Co., Elmira, N. Y.

KENNEDY
SAFETOP FIRE HYDRANT
REG. U.S. PAT. OFF.

EDDY

Valves and Hydrants

Distinctive Features of the EDDY Valves

ONLY three parts are moved by the Stem—the ball and the two gates. Each gate is hung from one of the trunnions on the ball. A convex surface at the base of each trunnion fits a concave surface on the back of the gate. This allows the gates to adjust themselves properly to their seats. . . . The gates, being free to revolve on the trunnions, do not always seat in the same position. Gates are center bearing and adjustable. They are forced to their seats with equal pressure at all points. There are two hooks on the ball on sizes 4-inch and larger, which loosely engage with the gates.

Distinctive Features of Our New Swivel Top Hydrants

THIS new hydrant has all the advantages of the popular EDDY fire hydrant, plus several additional features. . . . Nozzles are in a short flanged section of the standpipe, which may be unbolted and turned to different positions. . . . Should the standpipe be broken, only the casting below the swivel head need be replaced.

. . . To raise the hydrant to conform to a new grading, simply insert a flanged extension piece below the swivelhead. No digging. To add a steamer nozzle at any time, it is only necessary to replace the swivel head with one having a steamer nozzle.

Besides valves and hydrants to meet the most exacting demands of waterworks service, the complete EDDY Line includes: valves for sewage disposal works; valves for steam, gas and oil; check valves, foot valves, plug valves, shear gates, indicator posts, etc. EDDY valves are made in three classes: Iron Body Bronze Mounted, All Bronze, and All Iron Valves.

Eddy Valve Co.

WATERFORD NEW YORK

LEAD PIPE

Used by leading WATER WORKS for over 50 years. If proper weight is used, combined with good workmanship, your FINAL COST is assured, as REPAIRS are unnecessary. LEAD PIPE is sufficiently ductile to conform to any sagging condition. There is no RUSTING of pipe or joints; no DISCOLORATION of water.

LEAD WOOL

Every Atom Pure Lead

For calking pipe joints under the most difficult conditions; for overhead joints or in wet places where the use of molten lead is not only impracticable but dangerous — LEAD WOOL may be used to advantage.

It makes an absolutely tight joint which will withstand the highest pressure, yet be sufficiently elastic to allow considerable sagging or settling of the pipe, without danger of leaks.

Compared with the poured joint, in this respect, the superiority of LEAD WOOL is apparent.

LEAD PIPE TIN-LINED LEAD PIPE
PURE BLOCK TIN PIPE SOLDER
DUTCH BOY WHITE LEAD & RED LEAD

Highest Quality Soft Virgin Omaha Pig Lead

National-Boston Lead Co.

800 Albany St. Boston, Mass.

PLAY SAFE!

Specify LUDLOW HYDRANTS

Ludlow Hydrants are always ready for action — easy to maintain — easily repaired when broken off. They drain from the bottom to eliminate freezing; break only above ground; offer no obstruction to flow of water; prevent water hammer. And they are attractively modern. Send for free catalog.

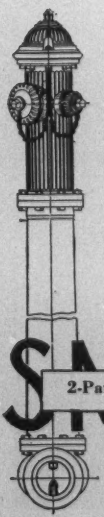
The LUDLOW VALVE MFG. CO.
TROY, NEW YORK

PUMPS { CENTRIFUGAL, STEAM, TRIPLEX, ROTARY
POWER { DIESEL, GASOLINE, STEAM, ELECTRIC
PARDEE CHLORINATORS { DIRECT, SOLUTION, VACUUM
PORTABLE { LABOUR SELF-PRIMING PUMP, AIR COMPRESSORS AND TOOLS

For Rent or Sale

HAYES
PUMP & MACHINERY CO.
125 Purchase Street Boston, Mass.
Hancock 7957--7958

Minimum Trouble and Expense When Breaks Come



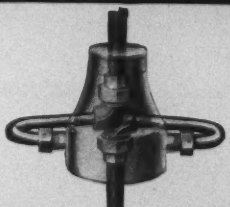
THE Smith Two-Part Standpipe Hydrant was designed to make the expense as small as possible when there is a break as the result, for instance, of careless auto truck driving.

The upper section will leakage of water because always break first. It can easily be renewed. And of course there can be no the main valve is of the compression type.

SMITH
2-Part Standpipe Hydrant

THE A. P. SMITH MFG. COMPANY
East Orange, N. J.

The Ford Copperhorn
MAKES AN IDEAL SETTING FOR METERS IN BASEMENTS



The COPPERHORN permits installing a water meter at the desired height in a vertical pipe. It provides an all-copper water way and maximum flow through the meter. It holds the customer's pipe connected and takes the curse out of meter changing. Let us tell you more about the COPPERHORN.

The Ford Meter Box Co.
WABASH, INDIANA

HAYS begins at the MAIN

Since 1869 Hays has built to the exacting requirements of the Water Works Industry. Tap the Main with a Hays Tapping Machine and follow through with dependable Hays Service Fittings for iron pipe, lead or copper. Hays Corporation Stops and Curb Stops are made in all styles and sizes. Write for Catalog.

HAYS RADIUS SEAL JOINT

This type of joint was designed to meet the specific requirements of certain Water Departments and is available directly on all styles of Hays Copper Service fittings.

HAYS DOUBLE SEAL JOINT

This joint features a 2-faced pipe flare (45° + 90°) and a 2-faced machined seal (45° + 90°) which is by test the strongest flanged connection available. Available by Adapter on any Corporation Stop and directly on more than 400 styles and sizes of Hays Service and Plumbing fittings.

USE THE HAYS COPPER SERVICE METHOD

Hays Adapts Copper to meet any Requirements

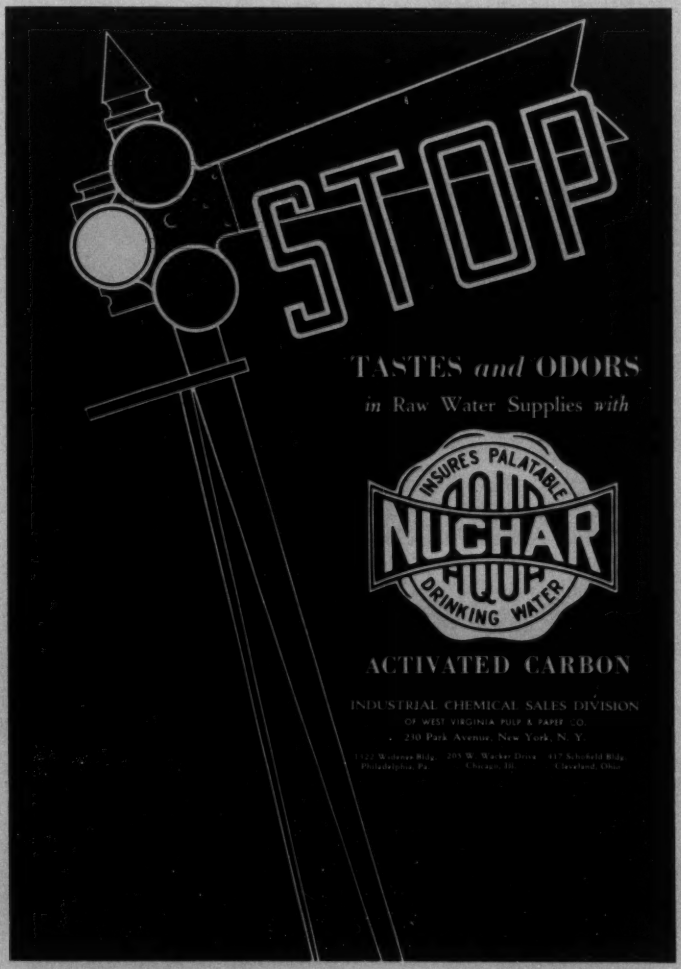
As a pioneer in the development of copper pipe services, Hays has popularized its use by making it easily adaptable to meet existing line equipment economically. Every community can have the advantage that copper pipe makes possible from Main to Curb to House with the Hays Copper Service Method. Let us have your problem.

HAYS MFG. CO.

ERIE, PA.

HAYS

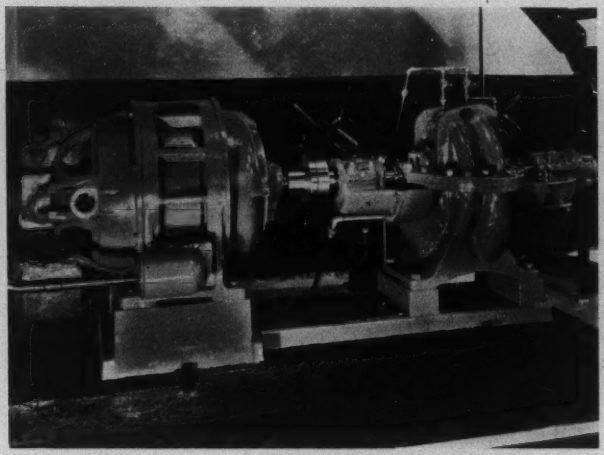
PLUMBING BRASS
BATH FIXTURES
COPPER PLUMBING
GAS SERVICE GOODS
WATER SERVICE GOODS
IRON PRODUCTS
TAPPING MACHINES


STOP
TASTES and ODORS
in Raw Water Supplies with
INSURES PALATABLE
NUCHAR
DRINKING WATER
ACTIVATED CARBON
INDUSTRIAL CHEMICAL SALES DIVISION
OF WEST VIRGINIA PULP & PAPER CO.
230 Park Avenue, New York, N. Y.
1522 Widener Bldg. Philadelphia, Pa.
205 W. Wacker Drive Chicago, Ill.
917 Schofield Bldg. Cleveland, Ohio

DE LAVAL

Pumps in East Providence, R. I. Water Department

All pumps in this Water Works Station are now De Laval



The latest addition to this plant is the two-stage centrifugal pumping unit shown in the above photograph.

The capacity of the new pump is 800 gallons per minute against a total head of 336 feet.

This pump was recently installed to replace an existing unit of another manufacture which was removed and the pumping station is now 100% De Laval equipped.

This station has an enviable record of high sustained efficiency with De Laval pumps over a period of years.

Complete contract by

TURBINE EQUIPMENT COMPANY

OF NEW ENGLAND

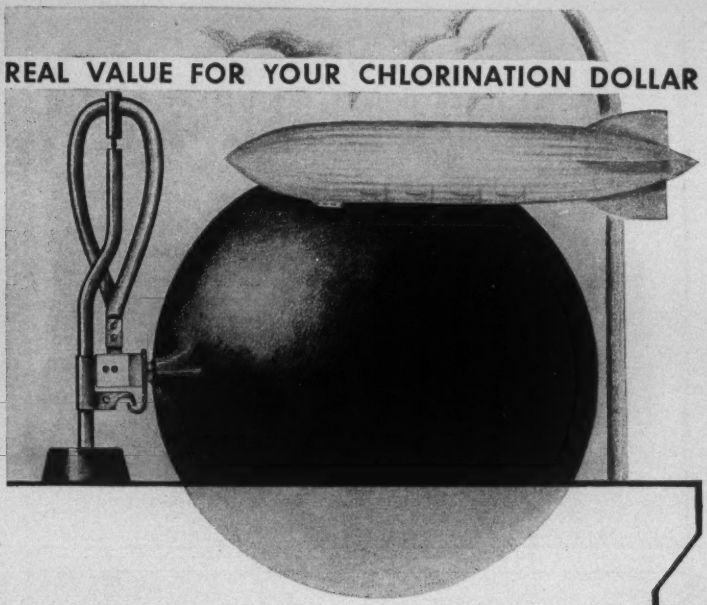
80 Federal Street **Phone LIBerty 5993-5994** **Boston, Mass.**

New England Representative for

DE LAVAL STEAM TURBINE COMPANY

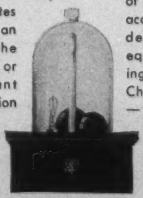
TRENTON, N. J.

REAL VALUE FOR YOUR CHLORINATION DOLLAR



Chlorination requires FLOATING POWER, TOO

POWER that floats on the water inside a bell jar controls the operation of a W&T Visible Vacuum Chlorinator No hidden diaphragms, no springs—only a needle valve operated by a floating hard rubber ball regulates the inflow of chlorine maintaining an even, constant pressure whether the equipment is feeding at its maximum or minimum. And not only a constant regulation, but a constant protection against escape of gas should the operating water supply fail. Immediately, the floating ball drops, seating the needle valve, and the gas is cut off until the trouble may be investigated and operation resumed.



Such carefully thought out design, coupled with meticulous attention to every small detail of material selection and manufacturing, accounts for the recognized accuracy, dependability and long life of W&T equipment. When specifying or purchasing equipment for the important job of Chlorination, be sure you call for W&T — for over twenty years the accepted standard of Real Value in the Chlorinator field.

Ask for Technical Publications 38, 157 and 158.

"The Only Safe Water is a Sterilized Water"

WALLACE & TIERNAN CO. INC.

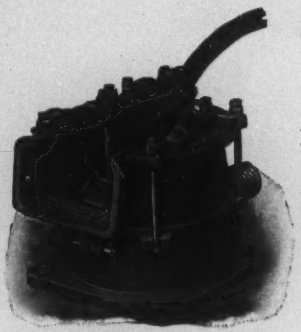
Manufacturers of Chlorine and Ammonia Control Apparatus

NEWARK, N. J Branches in Principal Cities

CHLORINATORS FOR WATER WORKS • SEWAGE PLANTS • SWIMMING POOLS • INDUSTRIAL PLANTS

SA-71

EDSON
PUMPS and ACCESSORIES



Hand Pumps – Power Pumps
Truck or Trailer Mounted
Edson Special Suction Hose
Red Seal Diaphragms
Edson Bronze Hydrant Pump
Strainers, Adapters, etc.

Distributors for
Pollard Pipe Line Equipment
Redi-Prime Pumps
Electric Pipe Thawers
Standard Hydrant Protector
Universal Water Leak Detector

THE EDSON CORPORATION
49 D Street, Tel. SOUth Boston 3041 South Boston
New York: 142 Ashland Place, Brooklyn

Warren Foundry & Pipe Corp.
ALSO
Warren Pipe Co. of Mass., Inc.

SALES OFFICES
11 BROADWAY, NEW YORK
75 FEDERAL STREET, BOSTON, MASS.

Manufacturers of

CAST IRON PIPE

Flanged Pipe ***Flexible Joint Pipe***
Bell and Spigot Pipe
Special Castings ***Short Body B. & S. Specials***
Warren (WF) Spun Centrifugally Cast Iron Pipe

WORKS: PHILLIPSBURG, N. J. and EVERETT, MASS.

Large Stock Enables Us to Make Prompt Shipments

Few Products In Any Field Are So Clearly Recognized for Superiority of Service As

SPUN **BITUMASTIC** LINING

REG. U.S. PAT. OFF.

The Report of the Committee on PIPE LINE COEFFICIENTS of the New England Water Works Association definitely proves the absolute economic necessity of lining all water pipe.

BITUMASTIC SPUN LINING is assigned a higher value of the coefficient *C* than any other lining. This insures the highest initial flow. More important —this high flow will be maintained for many years.

BITUMASTIC ENAMEL is not affected by tuberculating waters. Actual inspection of pipe in service and carrying tuberculating waters shows BITUMASTIC unaffected. This is real proof.

No taste, color, or odor imparted to the water.

Write for further information.

Wailes Dove-Hermiston Corporation

17 Battery Place, New York, N. Y.

The "COREY" Hydrant

Why you should use GENUINE COREY HYDRANTS

Water to Nozzles quicker than other Hydrants.

Standpipe can be removed and replaced without shutting off water in main.

Ease of operation insured by knuckle joint principle.

Only 13 turns to completely open or completely close, but full flow with only 4 turns.

Nozzles screwed in — not leaded.

Can be lengthened without shutting off water.

Will not flood if broken.

Positive Drip — cannot freeze.

Standpipe can be revolved quarter turns — Nozzles always in right direction.

Ask for our Catalog "G"

CHARLES L. BROWN,

New England Sales Manager, Lock Box 2, Northboro, Mass.

RENSSELAER VALVE COMPANY

TROY, N. Y.

DONALDSON IRON CO.

MANUFACTURERS

. . . OF . . .

CAST IRON PIPE

. . . AND . . .

Special Castings for Water and Gas
Also Flange Pipe and Fittings

EMMAUS, LEHIGH COUNTY, PA.

New York Office: E. A. NOONAN, 225 Broadway
New England Office: CHARLES F. GLAVIN, 35 Winslow Rd., Brookline, Mass.

WATER PROBLEM SOLVED BY NEEDHAM, MASS.

X. Henry Goodnough, Inc.
Engineers

● **The town of Needham can well be proud of its new water pumping station, for as city officials state, "Our water troubles will be over for a good many years to come." Believed to be the first Municipal Diesel driven Turbine Pump installation in New England, this system is equipped with a Fairbanks-Morse single-cylinder Diesel which powers an F-M Turbine Pump to economically supply the best quality water from an underground reservoir.**

Needham, as well as many other New England municipalities equipped by Fairbanks-Morse, is showing a substantial saving in operating costs. Get the facts on F-M power and pumping equipment by writing to Fairbanks, Morse & Co., 178 Atlantic Avenue, Boston, Mass.

FAIRBANKS-MORSE COMPANY

Power - Pumping - and - Weighing - Equipment

Water Works Officials

Cultivate the goodwill of your customers

Use the

METER-MASTER

To settle high bill complaints

The METER-MASTER is the only portable rate recorder that gives a continuous record for 6 and 24 hour periods, or 24 and 72 hour periods, from either a single or a compound meter.

F. S. BRAINARD & CO.
246 Palm Street
Hartford, Connecticut

Cement Lined Service Pipe

Cement lined pipe has eliminated corrosion and metal contamination for 60 years

Write for Literature

Cement Lined Pipe Co.
Lynn, Mass.

Your BELL and SPIGOT MAIN is No Safer or Stronger than its JOINTS!

Leaking joints mean expense for tearing up streets, traffic delays and hazards which none welcomes . Lay your mains to *stay* laid . Get tight, trouble-free and economical jointing with Tegul-MINERALEAD—the ingot-form, quick-sealing, sulphur base compound . Tegul-MINERALEAD offers you advantages not to be had in any other jointing compound.

A Tegul PRODUCT

Write for complete information

Tegul-MINERALEAD

The ATLAS MINERAL Products Company of Pennsylvania
Mertztown . . . . . Pennsylvania

Quick Sealing for Bell and Spigot Mains

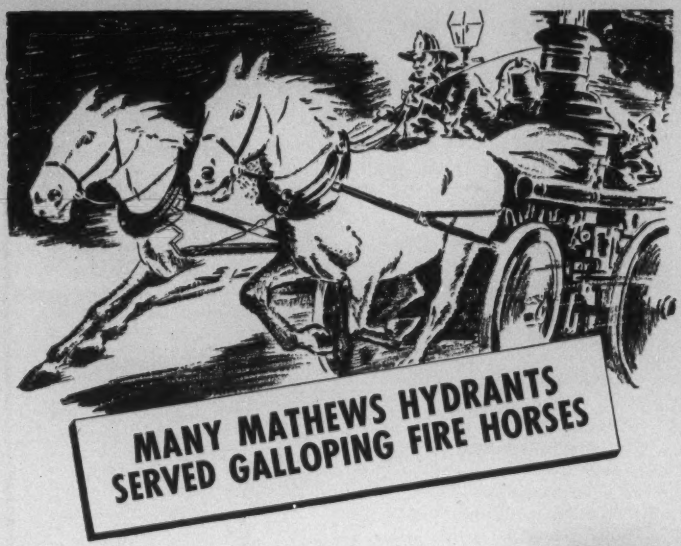
PIERCE - PERRY CO.

Wholesalers of

Water Works Brass Goods.
Byers Wrought Iron Pipe.
Youngstown Steel Pipe.
Valve and Service Boxes.

236 Congress St., Boston, Mass.

Telephone, Hancock 7817-7818

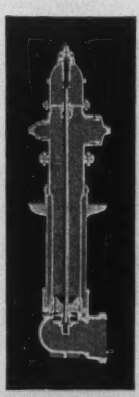


MANY MATHEWS HYDRANTS SERVED GALLOPING FIRE HORSES

● In many a town and city, the Mathews Hydrants which once awaited clanging bells and hoof beats now respond instantly to shrieking sirens and the hum of tires. Lots of Mathews Hydrants have unbroken performance records of 50, 60, and more years!

Today, progressive towns and cities are increasing and modernizing their protection by installing Mathews modernized barrels in those old protection cases. While the old hydrants still function—the steamer nozzles, revolving heads, shield operating nuts, and other improvements of modernized barrels are better equipment for modern fire fighting—and changing to Mathews modernized barrels is completely simple and economical.

No digging is necessary—new barrels fit the old protection cases and elbows. The entire Mathews barrel, including all working parts, can be unscrewed, removed, and replaced in 15 minutes from above-ground.



Send specifications today for prices

MATHEWS HYDRANTS

Made by R. D. WOOD COMPANY

Manufacturers of Sand Spun Pipe (centrifugally cast in sand molds) and R. D. Wood heavy-duty gate valves for water works

400 CHESTNUT STREET, PHILADELPHIA, PA.

CLASSIFIED DIRECTORY OF ADVERTISEMENTS

ACTIVATED CARBON.
Industrial Chemical Sales Division—West Virginia Pulp and Paper Co. xix

AIR CONDITIONING EQUIPMENT.
Worthington Pump and Machinery Corp. vii

AIR COMPRESSORS.
Hayes Pump and Machinery Co. xvii
Worthington Pump and Machinery Corp. vii

ASBESTOS CEMENT PIPE.
Johns-Manville xi

BRASS GOODS.
(See also Pipe, Brass.)
Caldwell, George A., Co. xiii
Cement Lined Pipe Co. xxv
Hays Mfg. Co. xviii
Mueller Co. xxxi
Pierce-Perry Co. xxv
Red Hed Mfg. Co. xxxii
Smith Mfg. Co., The A. P. xvii

CALKING MACHINERY AND TOOLS.
Mueller Co. xxxi
Smith Mfg. Co., The A. P. xvii

CAST IRON PIPE. (See Pipe, Cast Iron.)

CEMENT LINED PIPE. (See Pipe, Cement Lined)

CHECK VALVES.
Darling Valve & Mfg. Co. ix
Mueller Co. xxxi

CHEMICAL FEED APPARATUS.
Wallace and Tiernan Co., Inc. xxi

CHLORINATORS.
Wallace & Tiernan Co., Inc. xxi

CLAMPS, RIVER.
Dresser, S. R., Mfg. Co. Following front cover

CLAMPS, SERVICE.
Mueller Co. xxxi

CLEANING WATER MAINS.
National Water Main Cleaning Co. viii

COCKS, CURB AND CORPORATION.
Caldwell, George A., Co. xiii
Hays Mfg. Co. xviii
Mueller Co. xxxi
Pierce-Perry Co. xxv
Red Hed Mfg. Co. xxxii
Smith Mfg. Co., The A. P. xvii

CONCRETE PIPE. (See Pipe, Concrete.)

CONDENSERS.
Hayes Pump and Machinery Co. xvii
Worthington Pump and Machinery Corp. vii

CONTRACTORS' EQUIPMENT
Worthington Pump and Machinery Corp. vii

CONSTRUCTION EQUIPMENT.
Edson Corp., The xxii

CONSTRUCTION AIR TOOLS
Worthington Pump and Machinery Corp. vii

CONTRACTORS.
Layne-Bowler New England Co. iii
National Water Main Cleaning Co. viii
Reppucci, C. & Sons, Inc. iii
Ross, Anthony & Son iii

COUPLINGS, FLEXIBLE PIPE.
Dresser, S. R., Mfg. Co. Following front cover

COUPLINGS, REPAIR.
Caldwell, George A. Co. xiii

CURB BOXES.
Bingham and Taylor iv
Caldwell, George A., & Co. xiii
Hays Mfg. Co. xviii
Mueller Co. xxxi

CURB AND VALVE BOX FINDERS.
Caldwell, George A., Co. xiii

DIAPHRAGMS, PUMP.
Edson Corp., The xxii

CLASSIFIED DIRECTORY OF ADVERTISEMENTS *(Continued)*

ENGINEERS. Page

Bailey, Howard E. iii
Barbour, Frank A. ii
Barrows, H. K. ii
Crosby, Irving B. iii
Ellsworth, Samuel M. ii
Everett, Chester M. ii
Fay, Spofford & Thorndike ii
Goodnough, Inc., X. Henry ii
Metcalf & Eddy ii
Pirnie, Malcolm ii
Pitometer Co.
Thorpe, Lewis D. ii
Weston & Sampson iii
Whitman & Howard iii

ENGINES. (See Pumps and Pumping Engines.)

EQUIPMENT. (See Contractors' Equipment.)

ERECTORS, WATER WORKS AND POWER MACHINERY

Hayes Pump and Machinery Co. xvii
Turbine Equipment Co. xx

FEED WATER HEATERS.

Hayes Pump and Machinery Co. xvii
Ross Valve Mfg. Co. viii
Worthington Pump and Machinery Corp. vii

FILTER RATE CONTROLLERS AND GAGES. (See Rate Controllers)

FILTERS AND WATER SOFTENING PLANTS.

Ross Valve Mfg. Co. viii

FILTRATION PLANT EQUIPMENT.

Ross Valve Mfg. Co. viii
Wallace & Tiernan Co., Inc. xxi

FLEXIBLE JOINTS.

U. S. Pipe and Foundry Co. Facing back cover

FLAP VALVES.

Mueller Co. xxxi

FURNACES, ETC.

Atlas Mineral Products Co. xxv
Leadite Co., The Back cover
Mueller Co. xxxi
Smith Mfg. Co., The A. P. xvii

GATE VALVES. (See Valves.)

GUNITE.

National Gunite Contracting Co. iii

HOSE, SUCTION AND CONDUCTION.

Edson Corp., The xxii

HYDRANT PROTECTORS.

Edson Corp., The xxii

HYDRANTS, FIRE.

Darling Valve & Mfg. Co. ix
Eddy Valve Co. xv
Kennedy Valve Mfg. Co. xiv
Ludlow Valve Mfg. Co. xvii
Mueller Co. xxxi
Rensselaer Valve Co. xxiii
Ross Valve Mfg. Co. viii
Smith Mfg. Co., The A. P. xvii
Wood, R. D., Co. xxvi

HYDRANT PUMPS.

Edson Corp., The xxii

INSTRUMENTS. (See Water Works Instruments.)

LEAD.

National-Boston Lead Co. xvi

LEAD PIPE. (See Pipe, Lead.)

LEAD WOOL.

National-Boston Lead Co. xvi

LEAK FINDERS.

Pitometer Co. ii
Edson Corp., The xxii

CLASSIFIED DIRECTORY OF ADVERTISEMENTS *(Continued)*

METERS, WATER AND OIL. Page
Hersey Mfg. Co. ... v
National Meter Co. ... xii
Neptune Meter Co. ... vi
Pitometer Co. ... ii
Pittsburgh Equitable Meter Co. ... Following front cover
Worthington Pump and Machinery Corp. ... vii

METER COUPLINGS.
Ford Meter Box Co. ... xvii

METERS (VENTURI TYPE).
Mueller Co. ... xxxi
National Meter Co. ... xii

METER BOXES.
Bingham and Taylor ... iv
Ford Meter Box Co. ... xvii

METER MASTER.
Brainard, F. S. & Co. ... xxv

METER TESTERS.
Ford Meter Box Co. ... xvii
Mueller Co. ... xxxi

OIL ENGINES, DIESEL.
Fairbanks-Morse Co. ... xxiv
Hayes Pump and Machinery Co. ... xvii
Worthington Pump and Machinery Corp. ... vii

PAINTING.
Tredennick, J. H., Inc. ... Preceding index of advertisers

PIPE, BRASS.
Caldwell, George A. Co. ... xiii
Pierce-Perry Co. ... xxv

PIPE, CAST IRON (AND FITTINGS).
Donaldson Iron Co. ... xxiv
U. S. Cast Iron Pipe and Foundry Co. ... Facing back cover
Warren Foundry and Pipe Corp. ... xxii
Wood, R. D., Co. ... xxvi

PIPE, CEMENT LINED.
Cement Lined Pipe Co. ... xxv

PIPE, CONCRETE.
Lock Joint Pipe Co. ... Facing front cover

PIPE CUTTING MACHINES.
Smith Mfg. Co., The A. P. ... xvii

PIPE JOINTING MATERIAL.
Atlas Mineral Products Co. ... xxv
Hydraulic Development Co. ... x
Leadite Co., The ... Back cover

PIPE, LEAD.
National-Boston Lead Co. ... xvi

PIPE LINING.
Wailes Dove-Hermiston ... xxiii

PIPE, TRANSITE.
Johns-Manville ... xi

PIPE, WROUGHT IRON AND STEEL.
Pierce-Perry Co. ... xxv

PLUG VALVES.
Mueller Co. ... xxxi

PITOMETERS.
Pitometer Co. ... ii

PORTABLE AIR COMPRESSORS. (See Air Compressors)

POWER WIRE BRUSH, INC.
Tredennick, J. H., Inc. ... Preceding index of advertisers

PRESSURE REGULATORS.
Caldwell, George A., Co. ... xiii
Mueller Co. ... xxxi
Ross Valve Mfg. Co. ... viii

CLASSIFIED DIRECTORY OF ADVERTISEMENTS *(Continued)*

	Page
PROVERS, WATER.	
Pittsburgh Equitable Meter Co.	Following front cover
PUMPS AND PUMPING ENGINES.	
Edson Corp., The	xxii
Fairbanks-Morse & Co.	xxiv
Hayes Pump and Machinery Co.	xvii
Ross Valve Mfg. Co.	viii
Turbine Equipment Co.	xx
Wood, R. D., Co.	xxvi
Worthington Pump and Machinery Corp.	vii
RATE CONTROLLERS.	
SHEAR GATES.	
Mueller Co.	xxxi
SLEEVES, PIPE LINE REPAIR.	
Dresser, S. R., Mfg. Co.	Following front cover
SLEEVES, RIVER.	
Dresser, S. R., Mfg. Co.	Following front cover
SLEEVES AND VALVES, TAPPING.	
Ludlow Valve Mfg. Co.	xvii
Mueller Co.	xxxi
Rensselaer Valve Co.	xxiii
Smith Mfg. Co., The A. P.	xvii
SLUICE GATES.	
Mueller Co.	xxxi
STANDPIPES.	
Tredennick, J. H., Inc.	Preceding index of advertisers
SUPPLIES AND TOOLS.	
Caldwell, George A., Co.	xiii
Hays Mfg. Co.	xviii
Leadite Co., The	Back cover
Pierce-Perry Co.	xxv
Smith Mfg. Co., The A. P.	xvii
TAPPING MACHINES.	
Hays Mfg. Co.	xviii
Mueller Co.	xxxi
Red Hed Mfg. Co.	xxxii
Smith Mfg. Co., The A. P.	xvii
TAPPING SLEEVES. (See Sleeves and Valves, Tapping)	
VALVE BOXES.	
Bingham and Taylor	iv
Caldwell, George A. Co.	xiii
Ford Meter Box Co.	xvii
Mueller Co.	xxxi
Rensselaer Valve Co.	xxiii
Wood, R. D., & Co.	xxvi
VALVE INSERTING MACHINES.	
Smith Mfg. Co., The A. P.	xvii
VALVES, GATE.	
Darling Valve & Mfg. Co.	ix
Eddy Valve Co.	xv
Kennedy Valve Mfg. Co.	xiv
Mueller Co.	xxxi
Rensselaer Valve Co.	xxiii
Ross Valve Mfg. Co.	viii
Smith Mfg. Co., The A. P.	xvii
Wood, R. D., Co.	xxvi
VALVES, REGULATING.	
Mueller Co.	xxxi
Ross Valve Mfg. Co.	viii
WATER WASTE DETECTION.	
Pitometer Co.	ii
WATER WORKS INSTRUMENTS.	
Caldwell, George A. Co.	xiii
WATER WORKS JOURNALS.	
Journal of the New England Water Works Association	viii
WELL CONNECTIONS.	
Red Hed Mfg. Co.	xxxii
WROUGHT IRON PIPE. (See Pipe, Wrought Iron and Steel)	

H-10810
Meter Box
Cover

DESIGNED FOR YEARS OF SERVICE

Mueller Extension Service Boxes, Meter Box Cover and Meter Yokes have been designed to give years and years of service. The upper section of the Extension Service Box slides freely up and down in the base, absorbing any heavy shocks to the top or permitting frost heave without damage to the curb stop or water service pipe. The lids are of heavy cast iron and practically indestructible. Made in either Minneapolis or Arch Pattern Base.

Mueller Meter Box Covers have the unique worm type lock that can be opened only with a special key. When the key is turned to open, the worm *forces* the lid open, and in closing, it *pulls* the lid tightly against the cover and prevents entrance of dirt or cold air.

Mueller Meter Yokes are sturdy and compact and may be used with practically all meters. They serve as a permanent pipe fitting, maintaining the spacing and alignment of piping at all times whether the meter is in or out. The stop, elbow and expansion connection are all bronze, giving a full bronze waterway. Specify Mueller Products and get those *extra* years of service.

H-10840
Meter
Yoke

H-10300
Minneapolis
Pattern

H-10306
Arch
Pattern

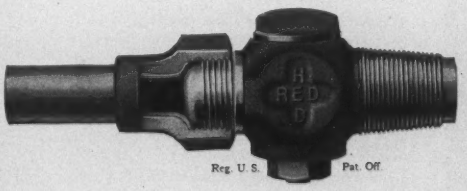
MUELLER CO.

Decatur, Ill.

THE BEST IS
THE CHEAPEST AND
MOST SATISFACTORY

H
RED
D

MFG. CO.



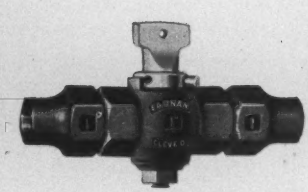
Makers of RED HED Brass Goods
For Water Works

368 CONGRESS STREET BOSTON, MASS.

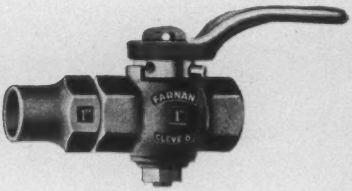
BETTER SERVICE CONNECTIONS

WHEN YOU STANDARDIZE ON

"FARNAN"



W-3680

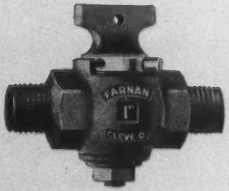


W-3640

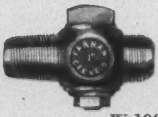
MEMBERS OF

AMERICAN WATER WORKS ASSOCIATION

SINCE 1892



W-3820



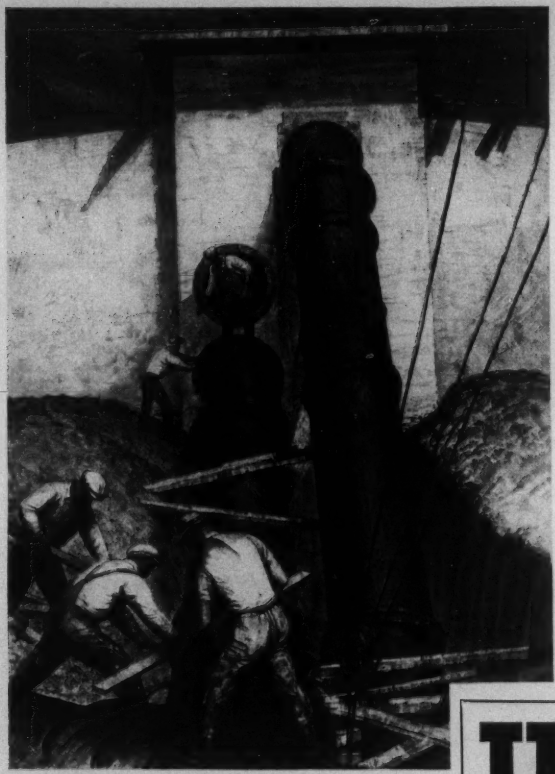
W 100

W-3720

FARNAN BRASS WORKS CO.

Established 1852

CLEVELAND OHIO



Lithographed on stone by James E. Allen for U. S. Pipe & Foundry Co. Copyright, 1937, U. S. Pipe & Foundry Co.

ADVANTAGES enjoyed by purchasers of U. S. Pipe are the *plus-services* made possible by strategically-located plants and storage yards; by complete and modern laboratory facilities; and by an expert technical staff. Co-operation in pipe design for unusual requirements, and strict adherence to exacting delivery schedules, can be counted on. We are organized and equipped to render a complete service in long-lived Cast Iron Pipe, either pit or centrifugally cast, for delivery anywhere.

U.S. cast iron PIPE

Cast iron pipe centrifugally or pit cast—for water works, gas, sewerage and drainage service as well as industrial uses involving corrosives.

U.S. Pipe & Foundry Co.
BURLINGTON, N. J.

Foundries and Sales Offices throughout the U. S.

The Journal of the New England Water Works Association

is a quarterly publication, containing the papers read at the meetings, together with reports of the discussions. Many of the contributions are from writers of the highest standing in their profession. It affords a convenient medium for the interchange of information and experience between the members, who are so widely separated as to find frequent meetings an impossibility. Its success has more than met the expectation of its projectors; there is a large and increasing demand for its issues, and every addition to its subscription list is a material aid in extending its field of usefulness.

All members of the Association receive the JOURNAL for two dollars per annum which sum is included in their annual dues; to all others the subscription is four dollars per annum.

TO ADVERTISERS

THE attention of parties dealing in goods used by Water Departments is called the JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION as an advertising medium.

Its subscribers include the principal WATER WORKS ENGINEERS and CONTRACTORS in the United States. The paid circulation is **1000** COPIES.

Being filled with original matter of the greatest interest to Water Works officials it is PRESERVED and constantly REFERRED TO BY THEM, and advertisers are thus more certain to REACH BUYERS than by any other means.

The JOURNAL is not published as a means of revenue, advertisements being inserted solely to help meet the large expense of publication.

ADVERTISING RATES

One page, one year, four insertions	Eighty Dollars
One-half page, one year, four insertions	Fifty-six Dollars
One-fourth page, one year, four insertions	Thirty-six Dollars
One-twelfth page (card), one year, four insertions	Twelve Dollars
One page, single insertion	Forty Dollars
One-half page, single insertion	Thirty Dollars
One-fourth page, single insertion	Twenty Dollars

Size of page, 4½ x 7½ net.

A sample copy will be sent on application.

For further information, address the Advertising Agent,

(Miss) MARCELLA SACHS,
613 STATLER BUILDING,
BOSTON, MASS.

LEADITE

THEY ALL LOOK GOOD AT THE START —

- - - - but in the Long Run ONE will prove SUPERIOR

Leadite is the pioneer self-caulking material for Cast Iron Bell and Spigot Water Mains . . . but, its performance on the job, proven thousands of times during more than 35 years, makes it the accepted Standard of water works men nearly everywhere. Leadite melts freely, pours easily and makes a good tight joint . . . furthermore, tests have shown that Leadite joints improve with age. Leadite effects very considerable savings.

Pick the winner . . . specify Leadite.

THE LEADITE COMPANY

Girard Trust Company Bldg. **Philadelphia, Penna.**

No Caulking